VOLUME VII. NUMBER 3

THE JOURNAL
OF
THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

DEVOTED TO THE ADVANCEMENT OF ASTRONOMY AND ALLIED SCIENCES

EDITOR

C. A. CHANT
University of Toronto, Toronto

ASSOCIATE EDITORS

W. F. KING
Chief Astronomer
Ottawa

R. F. STUPART
Director of the Meteorological Service of Canada, Toronto

J. S. PLASKETT
Dominion Observatory
Ottawa

PUBLISHED BI-MONTHLY

MAY-JUNE, 1913

PRINTED FOR THE SOCIETY
TORONTO: 198 COLLEGE ST.
FOREIGN AGENTS: WILLIAM WESLEY & SON,
28 ESSEX ST., STRAND, LONDON.

THE JOURNAL

OF THE

ROYAL ASTRONOMICAL SOCIETY

OF CANADA

VOL. VII. MAY JUNE, 1913. No. 3

An Extraordinary Meteoric Display	*C. A. Chant*	145
The New Reflecting Telescope of the Dominion Observatory	*W. F. King*	216
Location of Epicentres for 1912	*Otto Klotz*	229
The Orbit of 88 *d* Tauri	*W. E. Harper*	242
Meetings of the Society		
At Toronto	*L. G.*	248
At Hamilton	*T. H. W.*	251
At Peterborough	*D. B. M.*	252
At Winnipeg	*C. E. B.*	252
At Regina	*A. J. P.*	254
Notes from the Meteorologcal Service		
Report of the Weather in Canada, April-May	*R. F. S.*	261
Earthquake Records at Toronto and at Victoria, B. C.	*J. Y.*	264
Magnetic Observations	*R. F. S.*	266
Astronomical Notes		
Gain of Definition by Moving a Telescope		267
The Energy of the Rotating Earth		267
Radial Motion in Sun-Spots	*J. R. C.*	268
Notes and Queries	*C. A. C.*	269

Editorial communications should be addressed to C. A. Chant, University of Toronto, Toronto, Ont.

Business correspondence, remittances, etc., should be addressed to Chas. P. Sparling, Treasurer of the Society, 198 College Street, Toronto.

Communications regarding Library matters should be addressed to the Librarian.

$2.00 per annum. Single numbers, 35 cents.

Subscription to the *Journal* is included in membership fee.

Anyone wishing to purchase a telescope may correspond with the Secretary, Toronto.

THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

OFFICERS FOR 1912

Honorary President—W. F. KING, C.M.G., LL.D., Chief Astronomer, Ottawa.
President—Professor LOUIS B. STEWART.
First Vice-President—J. S. PLASKETT, B.A.
Second Vice-President—A. D. WATSON, M.D.
Secretary—J. R. COLLINS. *Treasurer*—CHAS. P. SPARLING.
Recorder—LACHLAN GILCHRIST, M.A. *Librarian*—DR. W. M. WUNDER.
Curator—ROBERT S. DUNCAN.

Council—The above Officers, and the following members:—Rev. Dr. MARSH, F.R.A.S., Peterboro; H. B. COLLIER, Phm.B., Toronto; Rev. I. J. KAVANAGH, M.A., S.J., D.Sc., Montreal; A. F. MILLER, Toronto; Sir JOSEPH POPE, K.C.M.G., Ottawa; R. M. STEWART, M.A., Ottawa; and Past Presidents ANDREW ELVINS, JOHN A. PATERSON, K.C., M.A.; R. F. STUPART, F.R.S.C.; Professor C. A. CHANT, W. BALFOUR MUSSON, Professor A. T. DELURY; and the presiding officer of each Centre as follows: R. M. STEWART, M.A.; T. A. S. HAY, C.E.; WM. BRUCE, J.P.; HECTOR LANG, B.A.; Professor N. B. MCLEAN and HENRY WESTOBY, ESQ.

OTTAWA CENTRE

Local President—R. M. STEWART, M.A.
Vice-President—F. A. MCDIARMID, B.A.
Secretary—R. E. DELURY. *Treasurer*—D. B. NUGENT.
Council—THOS. FAWCETT, W. E. HARPER, B.A.; R. M. MOTHERWELL.

PETERBOROUGH CENTRE

Local President—T. A. S. HAY, C.E. *Vice-President*—T. C. ELLIOTT.
Secretary-Treasurer—REV. D. B. MARSH, D.Sc., F.R.A.S.
Auditor and Curator—H. O. FISK, C.E. *Librarian*—HAL. CRANE.
Council—D. WALKER, B.A.; S. J. KEYES, B.A.; W. A. LOGAN, C.E.; J. A. SEGER, HENRY CARVETH, A. J. JOHNSTON, PHM.B.; D. E. EASSON, B.A.Sc.

HAMILTON CENTRE

Local President—WM. BRUCE, J.P.
Vice-President—W. A. ROBINSON.
Secretary—T. H. WINGHAM, B.A. Sc. *Treasurer*—SENECA JONES.
Council—REV. J. J. MORTON, EDGAR SCHOLES, MISS I. M. WALKER.

REGINA CENTRE

Hon. President—HON. MR. JUSTICE J. T. BROWN.
Hon. Vice-President—N. MACMURCHY, B.A.
President—HECTOR LANG, B.A. *First Vice-President*—JAS. DUFF, M.A.
Second Vice-President—Miss E. D. CATHRO, M.A.
Secretary—H. S. MCLUNG. *Treasurer*—GEO. SIMPSON
Auditor—W. G. SCRIMGEOUR, M.A.
Council—MISS CHISHOLM, WM. TRANT, P.M.; J. E. DOERR.

WINNIPEG CENTRE

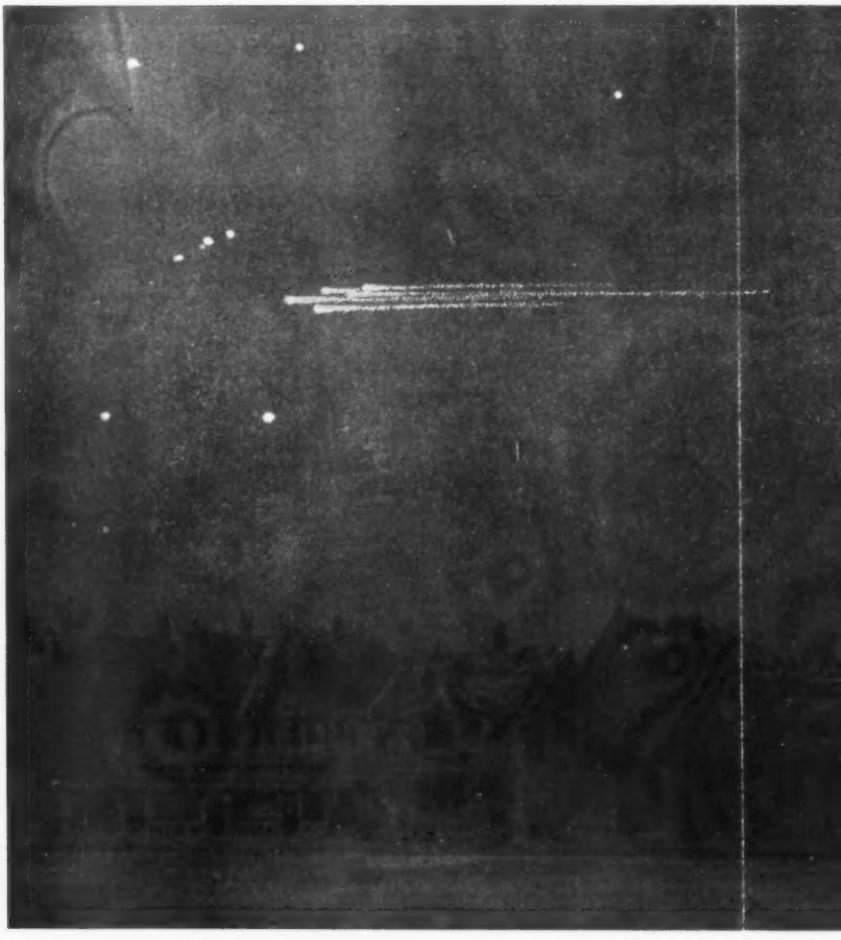
President—PROFESSOR NEIL B. MACLEAN.
Vice-President—L. A. H. WARREN, M.A.
Secretary-Treasurer—C. E. BASTIN.
Council—REV. FATHER J. BLAIN, S.J.; F. B. HUGG, H. C. HOWARD, J. H. KOLB, H. W. MALPASS.

GUELPH CENTRE

Honorary President—COLONEL A. H. MACDONALD, K.C.
Honorary Vice-President—DR. W. F. SAVAGE.
President—HENRY WESTOBY, ESQ.
First Vice-President—PROFESSOR W. H. DAY, B.A.
Second Vice-President—DR. J. LINDSAY. *Secretary*—H. E. S. ASBURY.
Recorder—J. T. LUTON. *Treasurer*—H. J. B. LEADLAY.
Curator—S. TERRELL
Council—W. TYTLER, M.A.; J. MCNIECE, B.A.; PROFESSOR R. R. GRAHAM, B.A., B.S.A.; DR. A. H. HOBBS, W. C. MCLAREN, MISS MARY MILLS AND MRS. W. O. STEWART.

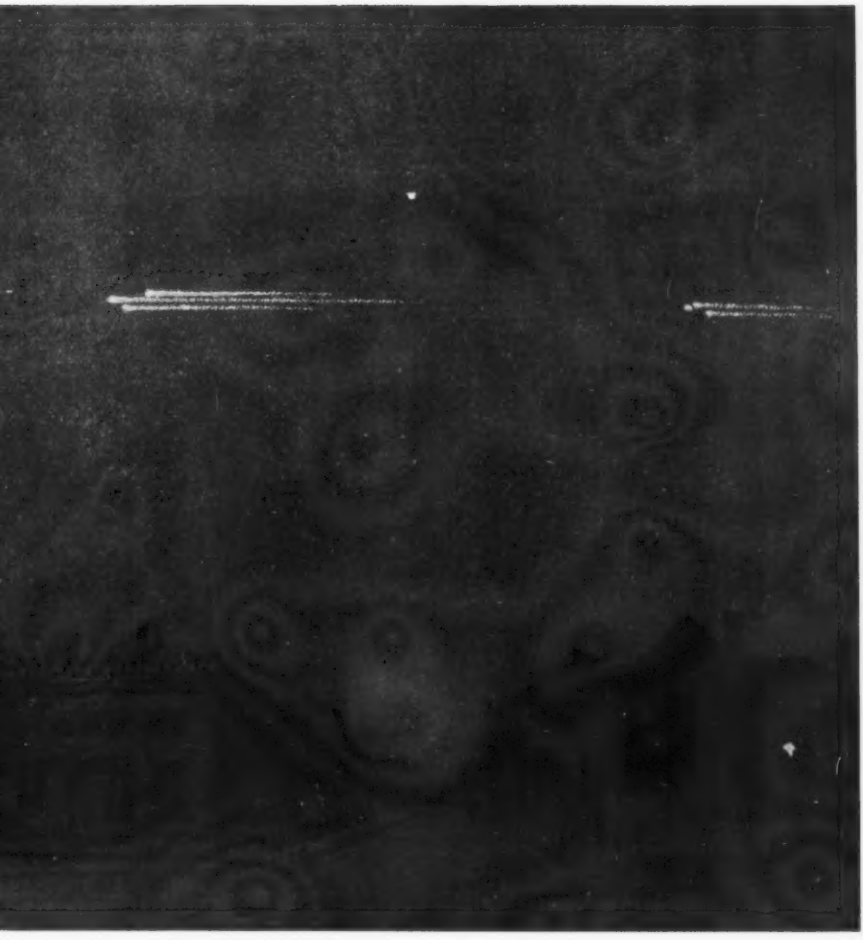
VI3 MAY JUN 1

XU



METEORIC DISPLAY OF
(From a drawing by Gusta
The above represents a portion of the display as observed by Mr
The spaces between succeeding clusters were act

PLATE IX.



LAY OF FEBRUARY 9, 1913
g by Gustave Hahn, Toronto).
rved by Mr. and Mrs. Hahn, in the vicinity of High Park, Toronto.
rs were actually somewhat greater than shown here.

THE JOURNAL
OF THE
ROYAL ASTRONOMICAL SOCIETY
OF CANADA

Vol. VII. MAY-JUNE, 1913. No 3.

AN EXTRAORDINARY METEORIC DISPLAY

By C. A. Chant

ON the evening of Sunday, February 9, 1913, the inhabitants of an extended portion of the United States and Canada witnessed a meteoric display which, as far as I can learn, is quite without a parallel. It was not my good fortune to be an eye-witness of the phenomenon, but when, a few minutes after it had passed, telephone messages were received describing it, I realised that there had been a very exceptional occurrence. Yet it was only on the following day, after interviewing various observers and reading the reports in the newspapers, that the truly extraordinary nature of the display was recognised.

I then decided to investigate the matter. In response to a request for reports of observations, courteously published in the daily newspapers of Toronto and repeated in some of the papers in others places, many letters and verbal communications were received. By reading the vivid descriptions and examining the illustrative sketches supplied by my correspondents, I have been enabled, in imagination, to view the wonderful spectacle again and again. The information supplied has also permitted me to

trace the path of the meteors with considerable accuracy and to determine various other facts connected with their flight.

My inquiries also revealed the fact that during a few hours before and after the great display several other striking meteors were observed, though I have not a complete enough record of the fireballs to enable me to compute their paths.

I propose to give, first, a brief general account of the display and then a statement of the conclusions I have reached regarding the path of the meteors, their height above the earth, their speed, the sounds heard, the duration of the display and the size of the bodies. After this I shall refer to other meteors seen within a few hours of the main display, and at the end I shall add extended extracts from many communications sent in. The reports regarding the great display, which extended from Saskatchewan to Bermuda, are printed first, the places from which they were recieved being arranged in alphabetical order; those referring to the other meteors appear together at the end. Along with the reports are reproductions of sketches sent with the letters. These were for the most part hastily drawn by people who have no particular talent for drawing, but they well illustrate what the text describes and are printed without any attempt to turn them into works of art.

The reader will be interested in examining these extracts from the letters. He will also see that intelligent people can differ widely in describing a phenomenon, and will be able to appreciate the difficulty I have had in discriminating between very discordant observations.

The numerous communications which I have received regarding this peculiar natural phenomenon have afforded me much pleasure, especially those sent by the boys and girls; and the readiness to respond to my requests for further information has been very gratifying.

GENERAL DESCRIPTION

[AS SEEN IN WESTERN ONTARIO]

At about 9.05 on the evening in question there suddenly appeared in the northwestern sky a fiery red body which quickly

grew larger as it came nearer, and which was then seen to be followed by a long tail. Some observers state that the body was single, some that it was composed of two distinct parts and others that there were three parts, all travelling together and each followed by a long tail.

The front portion of the body appears to have been somewhat brighter than the rest, but the general color was a fiery red or golden yellow. To some the tail seemed like the glare from the open door of a furnace in which is a fierce fire; to others, it was like the illumination from a search light; to others, like the stream of sparks blown away from a burning chimney by strong wind.

The first suggestion which occurred to many who saw the body was that someone had set off a great sky-rocket. In the streaming of the tail behind, as well as in the color, both of the head and the tail, it resembled a rocket; but, unlike the rocket, the body showed no indication of dropping to the earth. On the contrary it moved forward on a perfectly horizontal path with peculiar, majestic, dignified deliberation; and continuing in its course, without the least apparent sinking towards the earth, it moved on to the south-west where it simply disappeared in the distance.

As we all know, most shooting stars are visible for but a very short time, and the brilliant ones very generally descend rapidly towards the earth, seemingly (as one of my correspondents remarked) "in a mighty hurry to reach their destination"; but here were bodies moving leisurely along, giving ample time for the fortunate observer to make *several* wishes if he were so inclined. Some report that just before disappearing this body burst, leaving behind it a trail of stars.

Before the astonishment aroused by this first meteor had subsided, other bodies were seen coming from the north-west, emerging from precisely the same place as the first one. Onward they moved, at the same deliberate pace, in twos or threes or fours, with tails streaming behind, though not so long nor so bright as in the first case. They all traversed the

same path and were headed for the same point in the south-eastern sky.

Gradually the bodies became smaller, until the last ones were but red sparks, some of which were snuffed out before they reached their destination. Several report that near the middle of the great procession was a fine large star without a tail, and that a similar body brought up the rear.

To most observers the outstanding feature of the phenomenon was the slow, majestic motion of the bodies; and almost equally remarkable was the perfect formation which they retained. Many compared them to a fleet of airships, with lights on either side and forward and aft; but airmen will have to practice many years before they will be able to preserve such perfect order. Others, again, likened them to great battleships, attended by cruisers and destroyers. Should these bodies strike the earth they might prove destroyers indeed! Still others thought they resembled a brilliantly lighted passenger train, travelling in sections and seen from a distance of several miles. The flight of the meteors has also been compared to that of a flock of wild geese; to a number of men or horses in a race, and to a school of fish, startled and darting off in a single direction. These and many others interesting details will be found in the reports of observations printed below.

Just as the bodies were vanishing, or shortly afterwards, there was heard in many places a distinct rumbling sound, like distant thunder or like a carriage passing over rough roads or over a bridge. In some cases three such sounds, following at short intervals, were heard; while a number of people felt a shaking of the earth or of the house.

As to the number of bodies there is great diversity of statement. The usual estimate is from 15 to 20 but some say 60 or 100, while some say there were thousands. Various reasons can be assigned for the discrepancy between these numbers. Those giving the small numbers probably refer only to the chief bodies, and as some people have better eyesight than others, where one would see a single body others would see its

different parts. Those who report the large numbers undoubtedly included fragments of the larger bodies and also the many red stars bringing up the rear. The only person that I have heard of who viewed the meteors with any instrumental assistance was Master Cecil Carley, a pupil of the Trenton High School, who used an opera glass. He says: "There were about ten groups in all and each group, as seen through the opera glass, consisted of from twenty to forty meteors."

The entire time occupied by the display cannot be determined accurately, but is given below as perhaps 3·3 minutes. This is an extraordinarily long time for such a phenomenon, but there is good evidence that it is not an exaggeration.

The stretch of country over which the display was seen is also unprecedented. In September, 1868, a fire-ball was traced from over the Black Sea to France, about 1500 miles; and on December 21, 1876, such a body first became visible in Kansas and disappeared near Niagara Falls, thus covering a distance of over 1000 miles; but in the present case persons living 2500 miles (one-tenth of the earth's circumference) apart saw the same bodies. Moreover the description furnished by observers in Bermuda, in Ontario and in Saskatchewan do not materially differ.

In all ages comets and meteors have excited popular interest and in some cases alarm. Their appearance, entirely unannounced, their varied and extraordinary forms, as well as their almost inexplicable motions are well qualified to inspire terror to those unlearned in scientific matters. We are therefore not surprised to learn that some who saw this weird and unwonted spectacle were deeply impressed. One of my Toronto correspondents wrote: "It was a most beautiful sight. There were a number of us on the street watching them in the sky, and a remark from one of the ladies standing near me and who appeared to be in great distress, was that some dire calamity was coming to the earth. Another remark was, that they must be souls going to heaven, and so on, and a more or less serious impression was for the time being upon us all." Dr. Robert

Moore, of Fort Frances, who visited some Indian patients soon after the display states that an Indian remarked; "I am sure you will hear something. It must be the end of the world!"

THE PATH OF THE METEORS

As the meteors were observed at places a very great distance apart the *direction* of their path can be determined with considerable accuracy, though its exact location may be slightly in doubt. The place farthest west from which a report has been received was Mortlach, which is about 65 miles west of Regina, in Saskatchewan. Here they were described as travelling from west to east. At Pense, about 48 miles to the east, they were described as moving "in the sky directly overhead, in a direction from west to east."

When seen in Ontario the meteors were described as travelling generally from north-west to south-east, and sufficient observations were reported to enable one to determine with some definiteness a point which was directly below the path in the sky. From Campbellville the report states: "They passed *directly* overhead, travelling from north-west to south-east." At Hespeler, they "seemed to go right over our heads, or a little to the north." At Elora they appeared as "rising straight overhead." At Guelph, on plotting the path on a plan of the city streets, they seemed to have passed slightly to the south-west of the zenith. At Waterloo the course of the first was described as "almost directly overhead, but a little to the east." As to the rest, the majority were "a little to the east of us, with a few directly overhead, none to the west." At Berlin the course was judged to be 15° to the north-east of the zenith; at Georgetown, about 30° from the zenith; and at Sheridan, about 15° to the west of the zenith. Reference to the map (Fig. 1) shows that there is considerable discrepancy between these observations. Indeed, observers at points still farther away reported the bodies as having passed overhead.

However, we should not be much surprised at this. Unless a person has some definite objects to guide him it is very

difficult to judge angular distances correctly. To view a body directly overhead is extremely uncomfortable, and by most people a body is thought to be overhead when it is at a considerable distance from the zenith. Similarly, angular elevation of a body above the horizon is almost always adjudged too great. This question will be referred to again when discussing the height of the bodies above the earth.

In view of these conflicting reports it was necessary to arrive at some compromise, and the most probable path seemed to me to be a line passing almost over the city of Guelph, but a little to the south-west. The error in the location of this line may amount to three or four miles; and indeed it is well to remember that the meteoric bodies themselves were scattered over a path of perhaps this width.

The line on the earth's surface directly beneath the path of the meteors in the air, I shall call the *trace* of the meteors. This line cuts the 80th meridian in north latitude 43° 24′.

Now the observations show that the meteors were travelling practically parallel to the surface of the earth. It is true that some observers thought they detected a slightly downward tendency, but when seen a thousand miles farther on they were apparently as high, if not higher, in the air. The downward tendency, if it existed, was very slight.

It would seem that the bodies had been travelling through space, probably in an orbit about the sun, and that on coming near the earth they were promptly captured by it and caused to move about it as a satellite. It seemed reasonable, then, to consider the plane of the path as passing through the centre of the earth and hence cutting its surface in a great circle.

By means of the formulas of spherical trigonometry I determined the location on the surface of the earth of a great circle passing through Pense, W. Long. 104° 59′, N. Lat. 50° 25′, and the point in Ontario, W. Long. 80°, N. Lat. 43° 24′. In the accompanying table are given points on this circle ranging over two-thirds of the circumference of the earth.

TABLE I.

TRACE ON THE EARTH OF THE PATH OF THE METEORS

Longitude	Latitude	Longitude	Latitude
104° 59′ W.	50° 25′ N.	50° 00′ W.	21° 53′ N.
100 00	49 34	35 00	4 29 N.
95 00	48 28	20 00 W.	14 2 S.
90 00	47 06	0 00	33 20
85 00	45 25	20 00 E.	44 36
82 00	44 15	40 00	50 5
81 00	43 50	60 00	51 34
80 00	43 24	80 00	49 34
79 00	42 57	100 00	43 24
75 00	41 00	120 00	31 5
65 00	34 53	140 00 E.	10 38 S.

The first entry in the table is Pense, and the seventh is the determined point in Ontario; the succeeding points are on this line extended.

At Watchung, N. J., 22 miles west of New York City, an observer reported that the meteors appeared to be overhead. The line drawn as described passes a little to the south of this place. The meteors were also seen by observers in the Bermuda Islands (W. Long. 64° 50′, N. Lat. 32° 15′) and the calculated line runs 131 miles to the north-east. The display was seen at North Bay, Ont., 186 miles, and at Winchester, Ont., 221 miles, from its trace on the earth. It must be remembered, however, that Pense and the Ontario point, which we took to fix our line, may be a few miles north or south of the true path, and so the true trace might come somewhat (perhaps 10 miles) nearer to or farther from Bermuda.

The angles made with the east-and-west line by this line are:—at Pense, 12° 49′; at the determined Ontario point, 31° 14′; and when passing the Bermudas, 40° 46′.

From Mortlach, Sask., to Bermuda, the extreme points at which the bodies were seen, the distance is 2437 miles: from the determined Ontario point to Bermuda is 1184 miles. In figure 2 is shown the path from Mortlach to Bermuda.

As the observed path of the meteors was so extraordinarily long I thought it interesting to examine the position beyond Bermuda of the great circle over which they were believed to have passed. I found that it went over the South Atlantic Ocean, around the Cape of Good Hope at a distance of about 600 miles from it, through the Indian Ocean, and that the first land to be reached was Western Australia. Of course one cannot say that the bodies ever arrived there, though I would not be surprised to learn that they did. No reports of observations of the phenomenon by mariners have come to my notice.

THE HEIGHT OF THE BODIES ABOVE THE EARTH

Having determined the trace on the earth's surface of the path of the meteors, their height can be easily deduced if their angle of elevation at any place is known. Many estimates of this angle were communicated to me, but as a large portion of them were made without reference to any object whose elevation could be measured, these have not been of great assistance in fixing the height. A few, however, allow the deduction of definite results and, as we shall see, many of the others when interpreted properly corroborate these results.

In Toronto Mr. Gustave Hahn, to whom I am indebted for the sketch from which Plate IX. has been made, observed the bodies to pass about midway between Rigel and the Belt of Orion; and Rev. F. Herman, of Caledon East, in his report sketched the Belt and the sword and stated: "The meteors went over, or nearly over, the face of this group." Now a line joining Toronto and Caledon East, (see Fig. 1) is almost parallel to the path of the meteors and these places are only about 27½ miles apart. Hence at the two places the bodies would appear to take very nearly the same course in the sky.

Now at 9.05 p.m. E.S.T., February 9, in Toronto a point midway between Rigel and the Belt had an elevation of about 40° and azimuth 16° west of south. Taking the path of the bodies to make an angle of 31° with the east-and-west line we

find that if θ is the elevation of the bodies when nearest to us, that is as seen in a direction at right angles to their path,

$$\tan \theta = \tan 40^\circ / \cos 15^\circ,$$
$$= \tan 41^\circ.$$

That is, the elevation was 41°.

Then, measuring on the map* (see Fig 1) the distance of Toronto from the trace of the meteors, we find it to be 30 miles; and if h is the height of the meteors, we have,

$$h = 30 \tan 41^\circ,$$
$$= 26{\cdot}1 \text{ miles.}$$

As I have already remarked, the distance to the trace of the meteors may be in error 3 or 4 miles, and so the height is also doubtful almost to this amount.

The elevation from Mr. Herman's observations is about 43°, and his distance from the trace is 28½ miles; from which the height comes out to be 26·5 miles.

Rev. Dr. Marsh, at Springville, observed the meteors to pass mainly behind the top of a telephone pole, though he states that some were slightly above, some slightly below. Afterwards he found the top of the pole to have an elevation of 14° 58′ above the eye, and the line joining the observer to the pole made an angle of 49° with the north-and-south line.

$$\text{Hence } \tan \theta = \tan 14^\circ\ 58' / \cos 17^\circ\ 46',$$
$$= \tan 15^\circ\ 41'.$$

That is, the elevation of the meteors at the highest part of their path was 15° 41′. The distance of Springville from their trace on the earth is 91 miles, from which we have

$$\text{Height} = 91 \times \tan 15^\circ\ 41',$$
$$= 25{\cdot}5 \text{ miles.}$$

This agrees very well with the results just obtained.

The writer was much interested in the observations made by Mr. E. A. Norman, of Mill Bridge, (Hastings County).

* Measurements were made on a map of Ontario on a scale of 30 miles to the inch, not on the map from which this cut was obtained.

Mr. Norman was standing at the south-east corner of his barn when the meteors appeared at the south-west corner, seemingly just below the eave. A simple measurement of the height of the eave above the eye and the length of the barn gave the elevation of the meteors as 22°, as seen in the west. This leads to a height of 106 miles, an impossible result. At the writer's request Mr. Norman verified his measurements, and the only conclusion is that he was mistaken in thinking them up to the eave, although his statement that the first thought which came to him was that his barn was on fire at the eave is evidence to the contrary.

Mr. James G. MacMillan, B.A.Sc., of Toronto, estimated the elevation to be 30°, and afterwards verified it with a clinometer. This leads to a height of 17·4 miles, a result evidently too small. Mr. MacMillan explains, however, that he could not recover the precise position in which he stood when viewing the display, that he may have been 30 or 40 feet from it, which would explain the lowness of the result.

Mr. H. G. Murray, a student in mathematics at the University, when reporting to the writer first gave the elevation as 55°, but on a closer examination shortly after, he stated that he was confident it was not over 45°. This gives a height of 30 miles.

Again, when Mr. John Clark, of Moore Park, Toronto, was recounting to the writer all the circumstances of the display, he indicated the elevation above the south-west horizon, which was about 40°. This gives a height of 25·2 miles.

In Table II. are given the values of the height which I have deduced. The first three are the best determinations, and the average of these is 26·0 miles. In the last four cases the elevation appears to have been estimated with care, and the heights deduced are not greatly above the accepted value of 26 miles.

TABLE II.

HEIGHT OF THE METEORS

Place	Observer	Elevation	Distance to Trace	Height
Best Determinations				
Toronto	Hahn	41°	30 mi.	26·1 mi.
Caledon East	Herman	43	28½ "	26·5 "
Springville	Marsh	15° 41′	91 "	25·5 "
			Average	26·0 mi.
Other Determinations				
Toronto	Murray	45°	30 mi.	30·0 mi.
Toronto	Clark	40	30 "	25·2 "
Georgetown	McKay	60	17 "	29·4 "
Edgar	Jamieson	22½	72 "	29·8 "

As already remarked, the elevation above the horizon is almost invariably estimated too high. Robert Smith, in his "Compleat Optics," published in 1738, explains why this is so. To ordinary observation the sky does not appear to be a complete hemisphere but only a portion of one, the part overhead seeming to be nearer than that at the horizon. From experiment Smith showed that the arc of the sky appears to be shaped as in Figure 3, in which OZ the vertical height of the zenith is $\frac{3}{10}$ of OB the

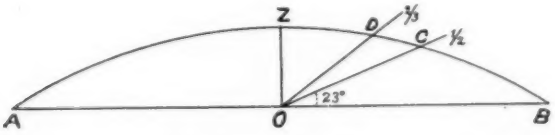


FIG. 3.—The curve AZB represents approximately the apparent shape of the sky. If the distance from O the observer to Z the zenith is 3 /10 of the distance from O to the horizon B.

distance of the horizon. Further he states, "By the eye we estimate the distance between any two objects in the heavens by the quantity of sky which appears to lie between them; as upon earth we estimate it by the quantity of ground which lies between them." Hence any point C will appear half-way between horizon and zenith when the arcs BC, CZ are equal; but by

actual measurement the angle *BOC* is found to be only 23°. When the arc *BD* is ⅔ of *BZ* the angle *BOD* is but 37°. That is, when an observer estimates the elevation of a heavenly body to be 45°, it is probably about 23° ; if the estimate is 60°, the true value is about 37°.

Interpreting in this way some of the estimates sent to me I obtained the accompanying table, though the results given in it must not be considered of very high scientific value.

TABLE III.

OTHER DEDUCED HEIGHTS OF THE METEORS

Station	Estimated Elevation	Corrected Elevation	Distance per Trace	Deduced Height
Dutton	45°	23°	78 mi.	32 mi.
Dresden	45	23	102 "	42 "
Rodney	45	23	93 "	38 "
Barrie (1)	50	25	66 "	31 "
Barrie (2)	45	23	66 "	27 "
Coldwater	45	23	86 "	35 "
Fenelon Falls	45	20	102 "	37 "
Elmvale	45	23	72 "	30 "
Parry Sound	37	17	115 "	32 "

In almost every case the height is too great but the results as a whole indicate the correctness of the explanation offered.

It would be very interesting to determine the heights of the meteors at the beginning and the end, as well as at the middle, of the observed flight ; but the data at hand are insufficient. In Saskatchewan no observations whatever are available for the purpose. Col. W. R. Winter, from his location almost in the centre of the Bermuda Islands, estimated the elevation at 35°. If they were 131 miles away, this would give a height of 92 miles. Colonel Winter estimated the angle by the branch of a tree on the road in front of him. This height is pretty certainly too high. Even supposing the value of the angle to be corrected in the manner explained above, it would be 17°, which would give a height of 40 miles. The indications are that the bodies rose

after leaving Ontario rather than that they fell, but evidence is not sufficient to finally determine the question.

THE SPEED OF THE METEORS

As the meteors were seen at places nearly 2500 miles apart it might be supposed that by obtaining the times when they were seen at the two extremes of this distance we could easily deduce the speed. But the entire time consumed in travelling this distance was very short, perhaps 4 or 5 minutes, and the times observed are not accurate enough to be used for this purpose. The time at which the phenomenon was seen is given as the same all along the line — 7 o'clock (M.T.) in Saskatchewan, 9 o'clock (E.S.T.) in Ontario, and 10 o'clock (Atl. T.) in Bermuda.

In my request for information I asked for estimates of the time during which a single body was visible. These varied all the way from 6 to nearly 60 seconds, but the ordinary values are from 20 to 30 seconds. From several persons in Toronto who observed the phenomenon I obtained estimates of the angle traversed during this time, varying from 120° to 135°.

Now at Toronto an angle of 120° would be subtended by 160 miles, and an angle of 135° by 192 miles of actual path. If traversed in 30 seconds this would give speeds of 5⅓ and 6⅖ miles per second, respectively. If the time taken was 20 seconds, the speeds would be 8 and 9½ miles per second, respectively.

The first value, 5⅓ miles per second, is probably too low. A body travelling close to the earth's surface as a satellite would perform a revolution in 84 minutes, or at the rate of 5·0 miles per second. This result is obtained on the assumption that the body is travelling in a vacuum. The bodies under consideration, though moving comparatively slowly, as their reddish color attested, were travelling in the atmosphere, and would surely have been brought to earth during their observed course if their speed had been so near that of a satellite in a vacuum. But, as we have seen, all observers agree in saying that the path was practically parallel to the earth's surface. I am inclined to

believe that the speed with respect to the earth's surface was greater than 5 and less than 10 miles per second.

Of course the velocity in space was greater. When seen the bodies were travelling largely in the direction of the earth's orbital motion, and also with the rotational motion of the earth.

THE SOUNDS HEARD AND THE DURATION OF THE DISPLAY

On the map (Figure 1) I have indicated those places at which sounds were heard, and it will be seen that they extend to a considerable distance from the path of the meteors. Those farthest away are Edgar,* 78 miles from the actual path in one direction and Cayuga, 33 miles in the other.

In some localities a shaking of the earth or of the buildings was detected. In the neighborhood of Shelburne this was especially noticeable. At Keldon Mr. Wm. Anderson "felt a slight tremor in the floor," and on going outside heard a rumbling noise, reminding him of a slight earthquake. A man living three miles farther west was in bed at the time and was awakened by the sound, and fearing that his horses were wrecking the stable got up to investigate,—only to find them perfectly quiet. I have learned of several in Toronto who detected the quivering of the house and remarked it at the time, among them being Mrs. and Miss Davis, of Poplar Plains Road. Many others heard the sounds.

In the Niagara peninsula these effects were very pronounced. At Niagara-on-the-Lake the windows rattled, and at St. Davids Rev. G. Munro heard the sound and looked in vain up in the sky to see the cause of it.

The sound has been compared to low distant thunder, to a wagon passing over hard rough roads or over a bridge, to the report of small arms in a sham battle at a distance; and a lady at Canfield likened it to the crashing together of two railway

*Dr. Jamieson, who reported from Edgar, did not hear the sounds himself but stated that others had. Several observers in Barrie did not hear the sounds. The places next farthest from the meteors where sounds were heard are, Unionville, 51 miles, and Jackson, 49 miles.

trains at a distance. In some places three distinct rumblings were heard, separated by intervals of a few seconds, while at others only one or two were detected.

In this connection it may be interesting to state that Mr. W. F. Denning, of Bristol, England, our leading authority on meteors, has recently expressed the opinion that many of the window shakings usually attributed to earthquake shocks are really due to the explosions of meteoric bodies high in the air. He has investigated a number of instances of this sort and has very strong evidence in favor of his view.

Knowing that sound travels at the rate of about 12 miles per minute, I have endeavored to compute the distance of the bodies by considering the interval between their passing and the hearing of the sound; the results are not very satisfactory.

It is pretty well agreed that the first bodies were the largest and most active of all. Some observers state that they burst into several pieces, and that they were continually giving off sparks which went to form their tails. It would naturally be expected that the interval between the passing of these bodies and the arrival of the first sound would be the time taken by sound to travel from its path to us.

Unfortunately the times are not accurately determined. The first bodies appear to have come well into view at about 9.05 (E.S.T.). Dr. Marsh, at Springville, gives it as 9.04½. Several in Toronto who consulted their watches give 9.05. An observer at Brampton gives 9.06 and one at Jarvis gives 9.08, as noted on a watch which may have been 50 seconds fast. Again, Mr. John Butterfield, of Toronto, states that on hearing the sound he immediately looked at his watch and the time was 9.12, which, he assures me, was closely accurate. From 9.05 to 9.12 is an interval of 7 minutes during which time sound would travel 84 miles, while the bodies passed within about 40 miles. Perhaps the sound heard was not produced by the first bodies.

Observers were also asked to state when the sound was heard; and some say just as the last bodies were disappearing,

while others say 1 minute, 2 minutes or 3 minutes after they had gone.

The estimates of the duration of the entire display also vary between wide limits. As has been stated, the beginning was in the neighborhood of 9.05, and Mr. Walter L. Haight, of Parry Sound, states that at the end of the flight he took out his watch and the time was 9.10. I have taken the average of 89 estimates, which run from 1 minute to 7 minutes, and find it to be 3·3 minutes. The bodies, when nearest to Toronto, were about 40 miles away, and sound would travel this distance in about 3·3 minutes. Hence, if the first noise heard was that produced by the first bodies it should have been heard just at the close of the display.

THE SIZE OF THE BODIES

It is interesting to consider the size of the bodies; but the observations again are very discordant and an accurate estimate is out of the question. However there is sufficient evidence to show that they were of considerable size.

Mr. Hewitson, of Jackson, states that the head of the first body was larger than the full moon, which is about 30′ in diameter. Mr. Norman, at Mill Bridge, estimates the leader to have been half the diameter of the moon, while Mr. White, of Coboconk, places the size as three-quarters of that diameter. Colonel Winter, in Bermuda, states that the apparent diameter of the leading bodies was equal to that of the moon. Jackson was about 50 miles while the other places were all more than 100 miles away. On the other hand Mr. Barber, a University student, states that he did not think the diameter to have been more than $^1/_{10}$ of the moon's diameter.

Referring to this matter, Young (*General Astronomy*, Art. 762) says:

"As seen from a distance of many miles, the meteoric fire-ball sometimes appears to have a diameter as large as the moon, which would indicate a real diameter of several hundred feet. The great apparent size, however, is an illusion, partly due to irradiation, and partly, undoubtedly, to the fact that the meteor itself

is surrounded by an extensive envelope of heated air and smoke which becomes luminous throughout. Probably no single meteor ever yet investigated was a solid mass as large as ten feet in diameter."

It may be pointed out, however, that these meteors were not intensely white as most fire-balls are, and so the effect of irradiation would not be so pronounced. Taking the diameter, as seen from Toronto, to have been $^1/_{15}$ of the moon's diameter, or 2′ of arc, this would give a diameter of 123 feet; while half the diameter of the moon as seen at Mill Bridge would correspond to a diameter of over 3000 feet. This latter value is probably a decided over-estimate, but I am inclined to think the largest bodies to have been at least 100 feet in diameter.

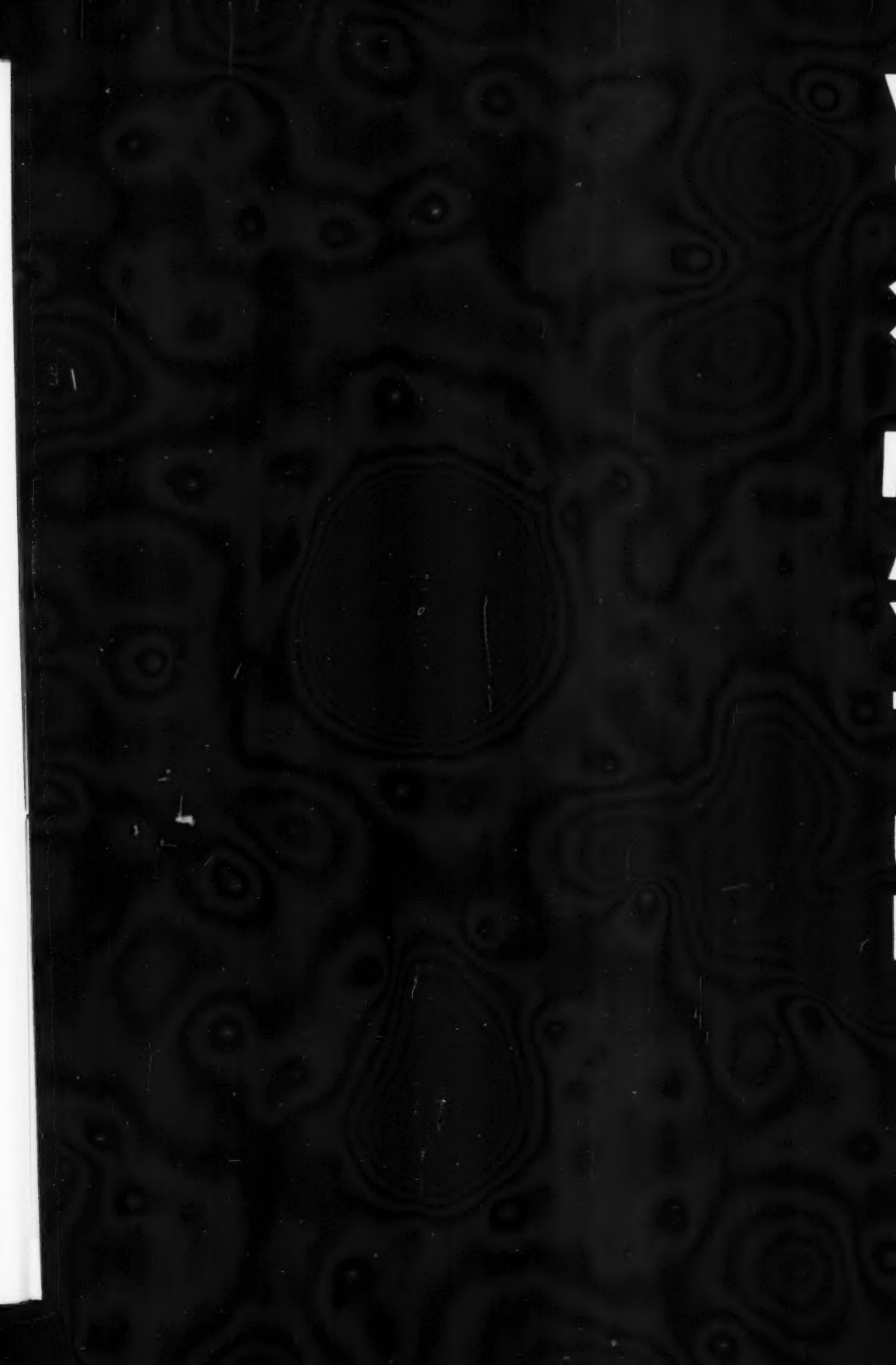
A rough approximation can also be made of the length of the tail of the largest meteor. At Centreton (see Figure 6) it appeared to be about 23° long, which would correspond to an actual length of 39 miles. Other estimates lead to an estimate of about this order, but all these values are liable to considerable error.

OTHER METEORS SEEN WITHIN A FEW HOURS OF THE GREAT DISPLAY

During the course of the present investigation the writer was greatly surprised and interested to learn that several other bright meteors were seen within a few hours of the great display. Extracts from letters received regarding these are given at the end of this account.

Mr. F. W. O. Werry, B.A., of Saranac Lake, N.Y., (W. Long. 74° 10′, N. Lat. 44° 20′) states that between 7.30 and 7.45, p.m. (February 9) he saw a shooting star begin about 10° higher up than Venus and move rapidly along a horizontal line (or nearly so) for about 30° towards the north. In a few minutes another meteor, starting in the same region, shot across the same part of the heavens, but its path was only about half as long.

Mr. J. G. Beatty, a student in Mathematics in the University of Toronto, living at Brampton, reports that at about 8.20 p.m., while watching Venus in the west, he saw a bright meteor



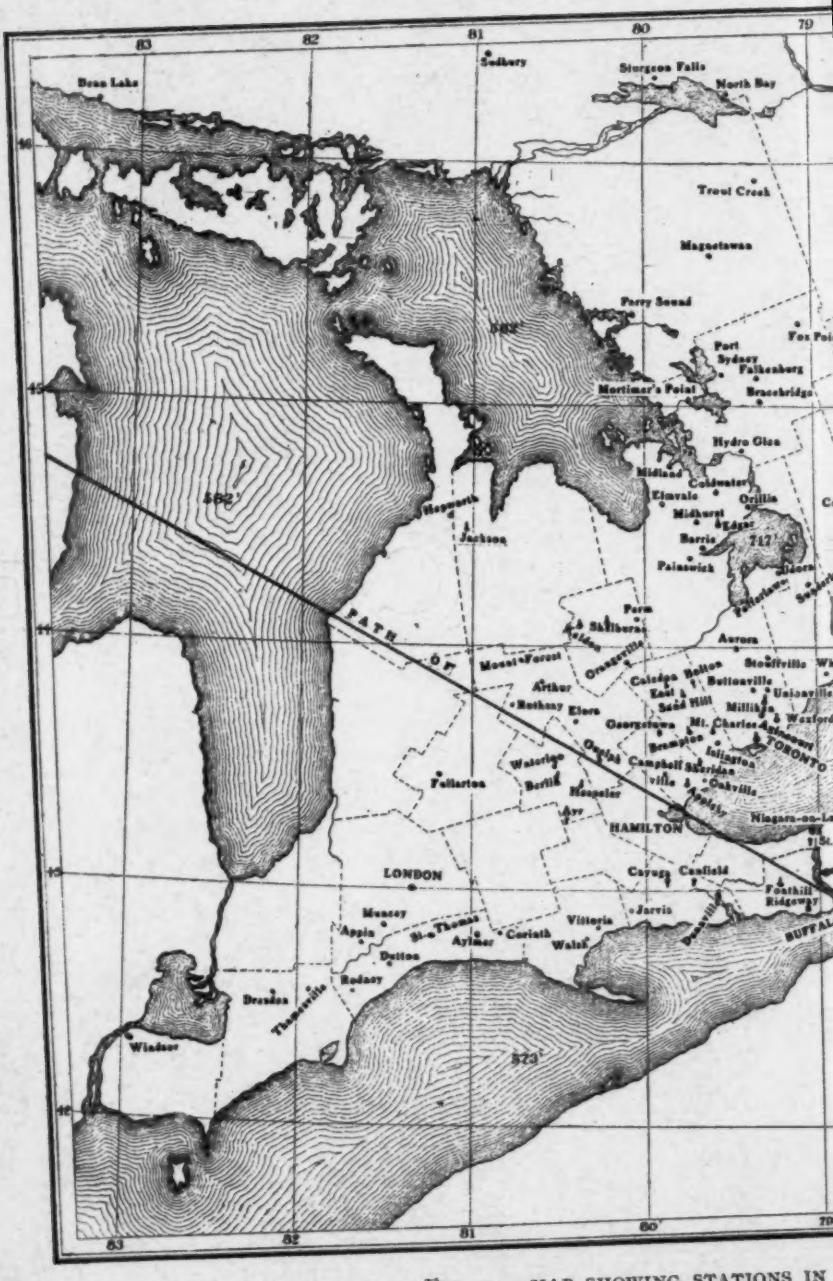


FIG. 1.— MAP SHOWING STATIONS IN
When crossing the 80th Meridian the

NS IN ONTARIO FROM WHICH REPORTS WERE RECEIVED.

ian the path made an angle of 31° 14′ with the E. and W. line.

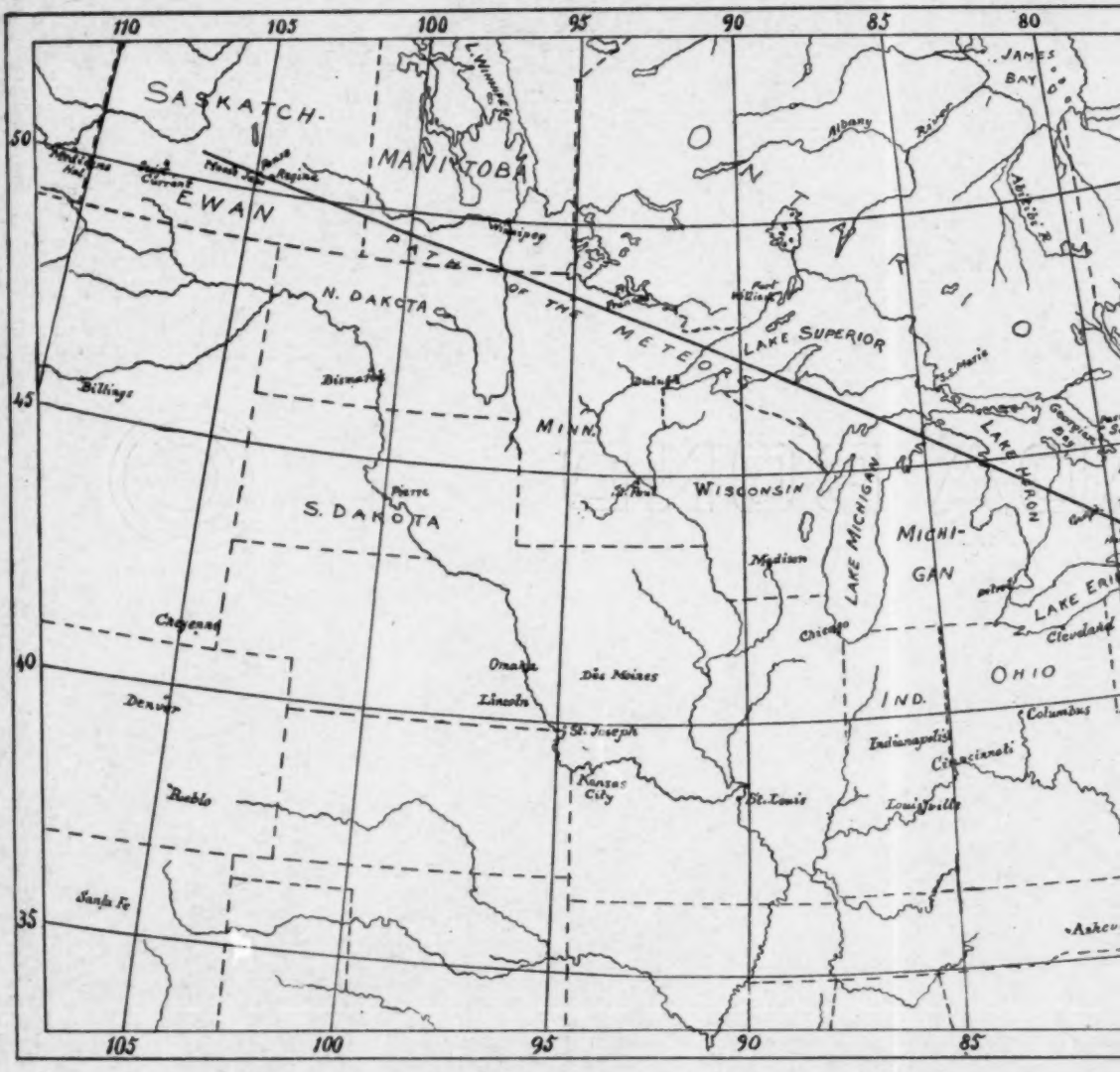
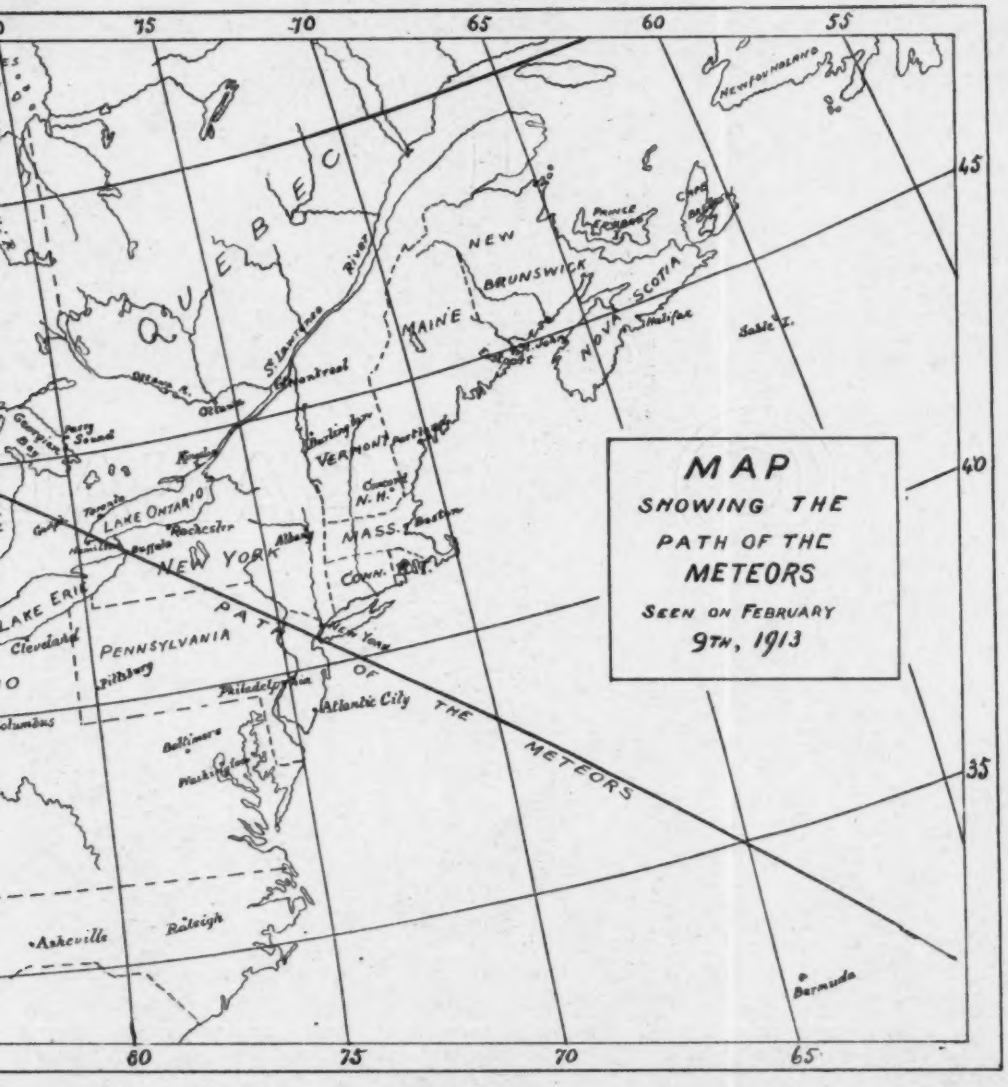


FIG. 2.— MAP SHOWING THE COURSE OF THE METEORS FROM SAS



FROM SASKATCHEWAN TO BERMUDA, NEARLY 2500 MILES

move quite slowly from north-west to south-east, apparently in about the same path as that taken by the great display 45 minutes later.

Mr. George H. Brooks, a teacher, of Roblin, Ont., states that at 9.30 he saw a meteor in the west which seemed to travel south or south-west, and which was visible for fully half-a-minute. It left a long trail behind.

Upon receiving Mr. Brooks's letter I first thought it referred to the great display, the time being in error by 25 minutes. But a communication from Mr. Walter Peters, the meteorological observer at Peterborough, led me to think otherwise. Mr. Peters stated that a reliable person at Peterborough had reported to him that he had observed between 9 and 10 o'clock a very bright meteor moving directly overhead from east to west. On intimating that I thought this was an isolated meteor, Mr. Peters consulted his informant, who was confident that he had seen the great display. I can hardly think so. Roblin is about 70 miles almost east of Peterborough, and I suspect that these two observations refer to the same object.

In *Popular Astronomy* for March, Mr. Lewis L. Mellor, of the Detroit Observatory, Ann Arbor, describes a very bright meteor which he observed at 10.15 p.m. (C.S.T.) (*i.e.* 11.15 E.S.T.) and which travelled towards the south-west. The object was brighter than Venus and its flight occupied 5 or 6 seconds. The body exploded violently, and the resulting flash of intense blue light illuminated the city for a fraction of a second. (For full details see below).

Another bright meteor was seen early Monday morning, and it is remarkable that it was reported by four observers from points many miles apart. Dr. J. J. Morrow, of Arthur (Wellington Co.), when returning from a sick call, was surprised to see the heavens light up for some seconds. The time he gives is about 1.15 ; and the light appeared to flash out of the northern sky. Mr. T. H. Banks, of Perm, (about 38 miles north-east of Arthur), saw the same meteor, the time given being 1.27 a.m. At Vittoria, (Norfolk Co., about 73 miles almost south of Arthur),

this meteor was seen by Mr. Joseph A. Montrose. The time given is 1.30 a.m. But the fullest account of it is by Mr. Geo. A. Deane, of the Circulation Department of *The Record*, Windsor, (161 miles south-west of Arthur). He had an excellent view of it and states that it was a remarkable phenomenon. The time was noted to be 1.23 a.m. Fuller details are given in Mr. Deane's letter, printed below.

For the report of Mr. Deane I have to thank Mr. F. P. Gavin, B.A., Principal of the Collegiate Institute, Windsor. He also furnished some observations by Mr. A. W. Brown, of Windsor, who was left as watchman at a train wreck on the C.P.R. near Bothwell. At about 9 p.m. Mr. Brown saw a bright meteor travelling from north-east to south-west. It was bright enough to attract the attention of one not watching for any such phenomenon. Again, at about 2.20 a.m. (Monday) he saw a series of less brilliant ones, though they were visible for a longer time. These appeared brightest about 70° or 80° above the horizon and seemed to travel right down to the earth.

In *Nature* for April 10 a correspondent living in the southern part of Patagonia (about 70° W. Long., 52° S. Lat.) who describes a fire-ball which visited that part of the world at about 6 a.m., Monday, February 10. As it was broad daylight it was seen only by a few, but violent sounds and vigorous shaking of windows were observed over a wide area. The direction of motion was east to west, which would correspond approximately to the direction in space taken by the great display of the evening before.

From England also comes a report of meteors about this time. In a letter to the writer, Mr. W. F. Denning states that very bright meteors were seen there on February 8, 9 and 10. He remarks that the date about February 10 is remarkable for meteoric fireballs, which sometimes have their radiant near Capella. Those seen by Mr. Brown may have been from this radiant.

In conclusion I shall refer to a curious observation reported in *The Toronto Daily Star* for Monday, February 10. At about

2 p.m. on that date some of the occupants of a tall building near the lake front saw some strange objects moving out over the lake and passing to the east. They were not seen clearly enough to determine their nature, but they did not seem to be clouds, or birds, or smoke, and it was suggested at the time that, perhaps, they were airships cruising over the city. Afterwards it was surmised that they may have been of the nature of meteors moving in much the same path as those seen the night before.

REPORTS OF OBSERVATIONS

PART I.

THE GREAT DISPLAY

In the following pages are given extracts from letters received from observers, the places from which they come being arranged in alphabetical order. In the brackets after the name of the place are given the distance in miles and the direction from Toronto, the direction being always referred to the nearest cardinal point of the compass.

Thus "Brampton, (16 miles, W. 8° N.)," means that this place is 16 miles distant and 8° north of west from Toronto.

Agincourt, 2 miles N. E. of (12 miles, N. 27° E.).

JAMES STONEHOUSE.

About 10 or 15 with tails seemed to be longer than the rest. At certain distances they seemed to be more clustered, the intervening spaces being filled with smaller ones, like stars, reminding one of the Milky Way, only so much brighter. There were thousands of them. Reports were heard, reminding one of a sham battle with small arms a long way off, but no explosions. They appeared first in the northwestern sky, about midway between the zenith and the horizon, and they disappeared in the same manner in the southeastern sky. They did not appear to drop towards the horizon, from which I would conclude they were very high. Duration, 3 or 4 minutes.

Appin (128 miles, W. 26° S.).

A correspondent reports the following statement as made to him:

A huge meteor appeared travelling from northwest by west to south-

east, which, as it approached, was seen to be in two parts and looked like two bars of flaming material, one following the other. They were throwing out a constant stream of sparks and after they had passed they shot out balls of fire straight ahead that travelled more rapidly than the main bodies. They seemed to pass over slowly and were in sight about five minutes. Immediately after their disappearance in the southeast a ball of clear fire, that looked like a big star, passed across the sky in their wake. This ball did not have a tail or show sparks of any kind. Instead of being yellow like the meteors, it was clear like a star. No sound was heard. Others reported seeing a shower of meteors, but they were not seen by the one who gives the above account.

Appleby (23 miles, W. 37° S.).

Miss Floy Priest.

About 9 o'clock or a little after as I was on my way home from church I saw a large meteor fall to the earth, leaving a tail of fire as long as Halley's Comet behind it. Then, turning towards the north, I saw a large black cloud, out of which shooting stars were coming, as it seemed, about 50, each having a line of fire in its path, and disappearing in a large black cloud in the south. After this there began a low rumbling sound like thunder.

Aurora (24 miles, N. 5° W.

G. A. Thomas.

They passed almost overhead, from northwest to southeast. The first group (about 15 or 20) resembled a shower from a rocket, only they moved in a straight line. It was followed by a smaller cluster, then two or three at a time; the whole lasting about one minute. They did not lower as meteors usually do, but appeared and disappeared as if obstructed by a cloud. Did not hear any sound or see any tails.

Aylmer (100 miles, W. 36° S.).

W. E. Stewart.

The display appeared to occupy a space in the sky about 10° wide, running almost from west to east, a little to the south. The upper edge appeared to have an elevation of about 70°. The meteors seemed to move at a uniform rate. First would be a cluster containing 25 or 30; then a few straggling ones; then another cluster. The larger ones, with the exception of a few extra bright ones, had the brightness of stars of the

second magnitude. A great many of these were in pairs, a short distance apart. These were again surrounded by very small meteors, some trailing out behind.

I did not hear any sound, and I would think the display lasted about two minutes. There were about 200 of the larger meteors in all, and the time for one meteor to traverse the course would be between 10 and 15 seconds.

The display appeared to come out from the west and move out of sight in the east, just as a railway train would.

Ayr (60 miles, W. 23° S.).

MRS. A. E. SARGEANT.

There were four distinct lots. As one died out another appeared in close succession. They looked like a mass of golden sparks, tapering off to a point. I stood at the northeast corner of the house, and the meteors started almost directly overhead and travelled at an angle from the corner of the house of nearly 45°. As they disappeared there was a distinct report, just like thunder.

Barrie (52 miles, N. 14° W.).

N. B. JOHNSTON.

I was walking westward when a large meteor appeared about midway between horizon and zenith, travelling about south-southeast, and going very slowly, that is, for a meteor. It was of a reddish color and had a long tail. When it had passed a distance south the tail broke into four pieces, and each part appeared to take on a head and continue in the same course until they disappeared—though not suddenly, as many meteors appear to do.

This one was followed by seven others, all of the same appearance and following each other in the same direction and apparently on the same line. The seventh and eighth were a pair, travelling parallel to each other. The first one was the only one that broke up. No noise was heard; each one was in sight 6 or 8 seconds.

JUSTINE J. MCBRIDE.

The path was about 50° above the horizon. Duration, about two minutes. No sound heard. The bodies were broken up and had tails. I think there were about 15 clusters.

C. A. Shepard.

Duration, 3 to 5 minutes. First was a group of 6 or 7 bodies. After that they came in singles and doubles. In one instance a fracture took place, forming a couple more bright spots. They travelled in parallel lines, apparently floating like gas balls, not appearing any lower at last than when first seen. Color, dull reddish yellow, like a burning coal. Total number, 15 or 20. No sound heard.

Mrs. Thos. Sibbald and Miss Gladys Firman.

The course was not directly overhead, but somewhat towards the south.

There appeared to be four groups. In the first were six stars with long streamers or tails; in the second, four stars with streamers or tails not so long or bright as in first group; in the third, two or three stars, with tails not so bright or long as in either of former groups; the fourth was merely like a large star or ball of fire, and it disappeared very quickly.

Duration, 3 to 5 minutes; no sound heard.

Berlin (58 miles, W. 15° S.).

A. W. Banfield (a missionary from W. Africa).

The meteors travelled parallel with the earth, and disappeared before they showed any signs of falling. I should say there were 20 to 25. From where I was standing, in the open, they were all visible at one time; all I had to do was to look in the direction from which they were coming and I could see them coming in groups—of four or five at a time.

The whole phenomenon lasted about two minutes, and as I stood waiting to see if any more would follow I heard a roar of thunder. I heard the thunder about one minute after the last meteor had passed. The bodies remained intact, but as they passed off the scene they seemed either to burn out or disappear in space. To me they seemed to have tails, and the proportionate length I will give in a small sketch (Fig. 4).

I was facing the east and the meteors were in front of me at about the angle shown. (About 15° from the zenith.—C. A. C.) It may be of interest to you to know that my wife was walking west on Galley Avenue (Toronto) on that Sunday night and she saw the meteors passing in front of her, i.e., to the west of her, at about the same angle that I saw them east of me. According to that they must have passed directly overhead somewhere between Toronto and Berlin.

Birdsall (74 miles, E. 33° N.).

M. M. Birdsall.

I should say there were more than a dozen. Three together particularly drew my attention. They travelled slowly and never lost their position relative to one another. The bodies I saw remained intact and had no tails.

Bolton (23 miles, W. 42° N.).

James H. Bolton.

When I saw the first meteor at 9.05 it was a little west of northwest from here and travelling nearly toward me. I took it for an aeroplane with both headlights lit, and as it came nearer the sparks falling behind it made it appear still more like one. However, after a minute or a minute and a half I could see it was a meteor, and the tail seemed to cover about half the sky distance when it was passing. It was very low, apparently just above the hills, and by this time I noticed about 12 or 15 more following it. Would guess that it was about 3 minutes from the time I saw the first and largest one until it got out of sight.

The smaller ones were going a little more slowly, and some of them died out just as they passed over, though they were not directly over me, but a little to the southwest. Would think it about 5 minutes from the time of first notice until they were all gone.

About 2 minutes after they disappeared there was a heavy noise like a clap of thunder at a distance. Half a dozen of us were together and all noticed it distinctly; in fact it was too heavy to go unnoticed.

There would be 12 or 15 passing at one time, so would think there were about 30 in the whole procession.

I have been fortunate enough to see nearly every big meteoric display for the past 50 years, but never saw anything as fine as this.

R. E. Caldwell.

They appeared in the western sky, about four-fifths of the way up from the horizon. As nearly as I can judge they lasted about one or two minutes.

There were about 40 or 50 in all. The first one was the largest, the next four smaller than the first but about equal to each other; the rest kept getting smaller until the last were mere red sparks. The largest ones had long tails of sparks, while the smaller ones had not.

The sound that was produced was a low rumble which at first made me think it was a buggy going along the road from church.

Bracebridge (95 miles, N. 4° E.).

E. J. Kirk.

The first meteor seemed to be a cluster of stars looking like a ball of fire. It came into view in the southwest, travelled close to the horizon towards the east.

A short distance behind the first cluster followed a small bunch of slightly bursting stars, which seemed to form the end of the tail or arrow; all the intermediate part appeared to be a streak of fire which partly hid from view the stars which had fallen into line and were keeping up the procession.

The first portion of the flight seemed to last nearly a minute, and this was followed by four or five similar processions of stars at intervals of a few seconds, but the succeeding ones were less brilliant.

Duration, about 2½ minutes; no sound was heard.

Bermuda (Waterville, Paget East).

Col. W. R. Winter.

Time: 10 p.m. Position: east of my position. Altitude, roughly 35° when opposite my point of observation. (Later.—I estimated the angle by the branch of a tree on the road in front of me, and got my angle from the spot next day. I may have been out a bit.)

Direction of motion: about northwest to south-southeast.

I saw two leading bodies like large arc lights in appearance, slightly violet in color; diameter, as far as the brilliance would permit of judgment, equal to that of the moon; one lower than the other and a little in advance of it. Both were coruscating or breaking into small pieces. As these pieces separated from the parent bodies they developed trails of sparks and gas. There were about 100 of these followers. Each had a nucleus, and perceptibly dwindled away in length as they got behind, from a length of about 13° near the head of the procession to small spots resembling pieces of wind-driven burning brown paper at the end. The longer ones were slightly scimitar-shaped and of a yellowish-red appearance, the nucleus being very bright. As they shortened up the color became more red, until at the last they were quite red, with a bluish flame above—exactly as if they were burning. These latter appeared to drift with the wind. The short ones preceding these were apparently egg-shaped. They were travelling horizontally, with a slight downward tendency as a whole.

I was unable to see the sky in the direction of Ursa Major, owing

to trees. I am informed that they appeared to come out of that constellation to people eastward of me.

I estimated that the display took 2 minutes to pass a given spot. It appeared to be travelling very slowly.

I enclose a rough sketch (Fig. 5) from a pencil sketch made at the time; this represents about three-fifths of the length, as I started on too large a scale. One-fifth more requires to be inserted at each arrow mark.

The trailers followed in groups divided by gaps, containing two only, and sometimes one. I counted 80 before getting mixed up.

It is impossible to sketch or describe the uncanny appearance of the display.

Mr. R. Ingham, who was four miles to the westward of my position (which was in Paget, due south of Hamilton, practically in the centre of the islands) reports that he observed them from a hill in Warwick, near the lighthouse. He mentions two leaders only, and states that one burst all to pieces when well away from the land.

From the east end of the island they appeared well to the eastward, and three leaders, well in advance of the two seen by me are reported by one man. No one else saw these as far as I can ascertain.

G. A. Outerbridge.

In a letter in "The Royal Gazette" of February 27, Mr. Outerbridge states that he saw three exceptionally large bodies throwing out a stream of sparks. "Then came two, not so bright, also emitting sparks; then a cluster of five, and then it seemed as if all the stars had made up their minds to move southerly. No sparks were thrown out by any but the first five."

Mr. Outerbridge counted upwards of 80 bodies, but another correspondent informs the present writer that some of his friends did not think there were as many.

Brampton (16 miles, W. 8° N.).

J. G. Beatty (University Student in Mathematics).

Did not see the meteors, being in the house, but heard the noise, like thunder, loud at first and rumbling every 2 or 3 seconds. Lasted about 2 minutes.

A. G. Berry.

Position in sky: a little west of the point overhead. Number: 15 in all, one at a time, but they followed each other quickly. Duration: 3

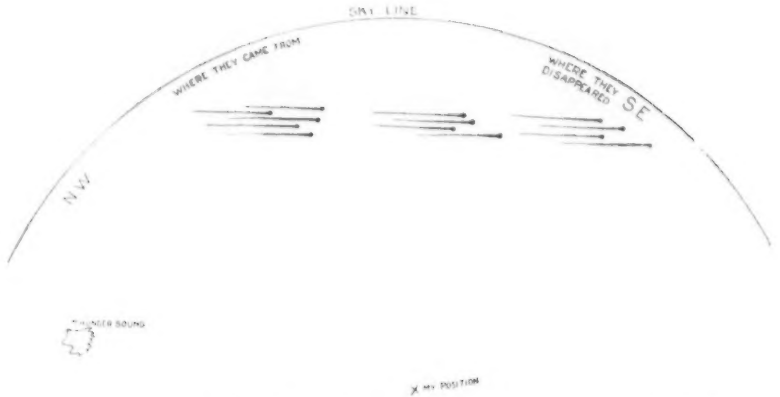


FIG. 4.—The flight of the Meteors, as sketched by Mr. A.W. Banfield at Berlin. The observer was at X and faced north-east. The place where the sounds appeared to come from is indicated in the left foreground.

FIG. 5.—From a rough sketch of the Meteoric Display made by Col. W. R. Winter, Bermuda. Apparent course N.W. to S.S.E. Wind, N.W. about 20 miles. This represents about 3/5 of the entire display, 1/5 more requires to be inserted at each arrow. (The curvature of the tails must have been apparent, not real.—C. A. C.).

to 4 minutes. Sounds: the first was the loudest, like a horse and rig going over a bridge; the other was not so loud, and both sounds were short. They occurred last of all. The bodies were intact, and each had a tail. Each was in sight, I should think, about 15 seconds.

E. P. Coish.

Saw the phenomenon and heard a sound like a wagon passing over a rough road.

Brighton (87 miles, E. 18° N.).

J. H. Morrow.

The first was brighter than Venus, and took perhaps a minute to travel its course. It had a trail behind it about 10° long. The second and third were not so bright, but moved similarly. Think there were over a dozen bodies. The course seemed to be about 30° above the horizon, and the entire duration was from 1½ to 2 minutes.

Buttonville (14 miles, N. 8° E.).

Mrs. R. B. Elliott.

A few seconds after seeing the first body, the second appeared. It shot a stream of brilliant stars, which formed a long tail. This body was the largest of all. I counted 19 bodies. Two went out before reaching the place where the others disappeared, and the other 17 were in sight at one time. No sound was heard.

Caledon East (29 miles, W. 29° N.).

Rev. F. Herman.

Saw two main displays. The first I mistook for a sky-rocket, which, after going some distance, appeared to open towards me. Before it had disappeared the other was well in sight, seeming to have about the same formation, following the same course with the same speed.

The centre meteors seemed to have no tails, being about the size of large stars, and having nearly their brilliancy. There may have been a dozen or so within the "tail" of the first.

Between the two displays, and after the last one, hundreds of dull-red sparks followed, giving the stars the appearance of being all in rapid motion.

A noise like a distant roll of thunder, probably lasting 4 seconds, was heard at least 4 minutes after the first display. From the first appearance to the last of the sparks, probably 4 minutes. Each display

took nearly 45 seconds to complete its course. The middle of the course, which was to the southeast, was about 40° from the zenith. The meteors went over, or nearly over, the Belt of Orion.

W. S. Jones.

Time, 9.07 or 9.08. The whole lasted about 2 minutes, and the next minute there was a noise like a short crash of thunder, and I imagined that the ground shook under me. About three-quarters to the end there was a big star with no tail, alone, with a few following.

Campbellford (91 miles, E. 30° N.).

Mrs. Wm. Humble.

The meteors were low down in the sky, travelling towards the east I think I saw at one time about 20. There were three very distinct ones, near together, but yet clearly separate. Others followed, and some disappeared before the three distinct ones I speak of. Think the display lasted 2 minutes. No sound. There were tails to each one, just narrow ones.

J. T. Vosper.

Gives information communicated to him by eye-witnesses. The first meteor was of a bright white color, with a long and distinct tail resembling a comet. It was attended, or surrounded, by a number of smaller meteors of a bright red color. Following this came a group of red meteors, but unlike the first from the fact that there was no "ball" of light or comet-tail—simply a group moving in the same direction. Then came another group, resembling the second, all quite brilliant and distinct. A fourth group followed, but it was composed of three meteors; and a fifth group, of only two, yet a bright red. The groups remained about the same distance apart from first to last. Duration, about 2 minutes.

A second person says he saw one meteor disappear as if it had exploded.

Campbellville (30 miles, W. 20° S.)

Rev. William Burt.

They passed *directly* overhead, travelling northwest to southeast. I did not count them, but should say there were 50 or 60. Duration, probably 3 minutes. The only sound I heard was a faint whistling like that of bullets whilst they passed overhead. The bodies remained intact until they reached half-way to the horizon, when they simply disappeared.

The first appearance was that of a large body, very bright, having a long fiery tail—very much like a comet.

Canfield (50 miles, S. 22° W.).

A woman living near Canfield heard a noise which she compared to the crashing together of two trains, or some terrific explosion in the direction of Hamilton.

Cayuga (52 miles, S. 27° W.).

T. J. Craven.

There were not only a dozen or fifteen meteors, large and small, but I don't think I am exaggerating when I say there were hundreds. The duration was from 2 to 4 minutes, and in color they were reddish, not like ordinary stars. Some of the large ones had long tails. After the meteors had all disappeared we heard a noise like thunder, apparently north of us.

Centreton (74 miles, E. 23° N.).

John T. Ormiston.

We went to the south end of the house to get a better view, and as far in that direction as we could see there were meteors. There were seven or eight ahead of the larger one shown in sketch (Fig. 6), so we had missed seeing the first. About seven passed after the large one, and we are sure we saw twelve. They were all in view at once and for the space of 2 minutes. When all had passed we looked at the clock and it said 9.15.

Coboconk (76 miles, N. 24° E.).

J. B. White.

I think they were in view 1½ or 2 minutes, and I counted 13 in sight at one time. I think there were 20 in all. They travelled on an exact level with the ground.

The tail kept the one size throughout its length, as if drawn through a tube. I believe when the large one was opposite me the tail was one-quarter the length of its flight; or perhaps 50 times its own length, supposing it to be a round body. The body looked about three-quarters the size of the full moon.

The course of the meteors was about 20° above the horizon. They were very low, compared with anything I ever saw before.

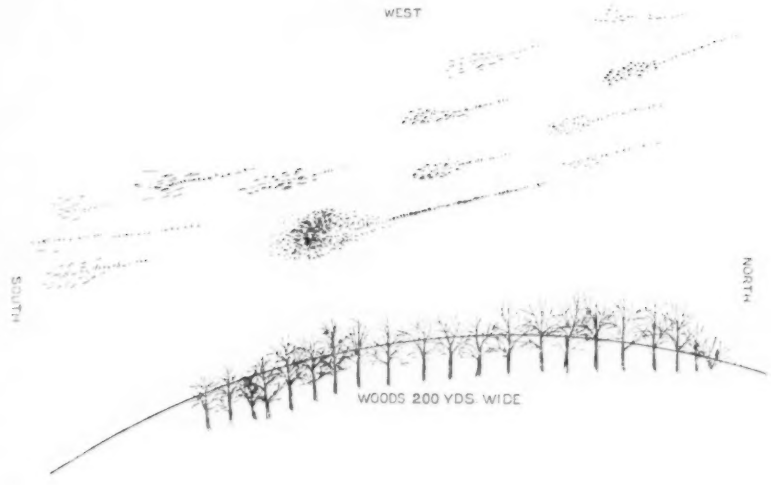


Fig. 6.—From a sketch made by Mr. J. T. Ormiston, Centreton. The woods in the foreground are about 200 yards wide and the meteors were observed from a point X, about 200 yards in front. The woods, therefore, subtended an angle of about 55° and the tail of the longest meteor shown was from 21 to 26° long.

Cobourg (64 miles, E. 19° N.).

J. E. Skidmore.

They glided along so leisurely and did not seem to be falling as meteors usually do, but kept a straight course about 45°, or a little more, above the horizon. Our first impression was that a fleet of illuminated air-ships of monstrous size were passing. The incandescent fragments themselves formed what to us looked like the illuminations, while the tails seemed to make the frame of the machine.

Sometimes there would be just a single collection, forming a single ship; then in a half-minute several collections would pass, looking like ships travelling in company. It took fully 3 minutes to pass. There was no noise; only beauty, beauty!

Coldwater (71 miles, N. 7° W.).

J. L. Shields.

Time, about 9.08. Bodies came out of northwest and disappeared in southeast without any perceptible fall. Position in sky, about 45° above horizon. About 20 seen in all, 8 or 10 being visible at one time. Duration of display, about 2 minutes. Brightest meteor was in sight about 45 seconds. No sound.

The largest meteor, which came first, proved to be two or three abreast, the sparks from them intermingling and forming one long tail, the whole apparently merging into one body again as it passed farther away. The first was followed by many more, going at the same speed and the same direction, but not all in the same path, some being above the line of flight of the first one while others were below.

Consecon (98 miles, E. 15° N.).

Cecil Carley (a student of Trenton High School).

There were about ten groups in all, and each group, as seen through the opera glass, consisted of from twenty to forty smaller meteors. The leader of the group was generally the largest, the smaller ones following closely behind.

The first group had the largest number and was led by a large body which was brighter and larger than all the rest. Each separate body had a tail which was from five to fifteen times as long as the main part, which seemed to diminish and go into the tail. Some seemed to break up into smaller bodies.

About three or four groups were seen at a time, the three appearing to the northwest, while the fourth was passing in the middle of its course. Each group was in sight from 15 to 25 seconds, and the duration of the whole phenomenon was about 5 minutes. No sound was heard.

Corinth (92 miles, W. 37° S.).

Will Beattie.

Time: shortly after 9 p.m. *Direction*: from the north-west to the south-east, and slightly downward. *Number*: would judge 15 or more, and some may have passed before I saw them. *Size*: The first ones were larger and brighter than the brightest stars and had tails which looked as long as the distance between the "Pointers" of the "Dipper." The last ones were like very faint stars.

I believe some of them were visible for as long as 10 seconds, and

the whole thing lasted between 2 and 3 minutes. I did not hear any noise, but was riding in a buggy over frozen roads.

Deseronto (120 miles, E. 18° N.).

Miss Lena J. Warren.

The first meteor looked like a fiery streak or bar when it came out of the north-west. When it had traversed about a quarter way across the sky it broke into four fiery red stars with long fiery tails, which fell into the position shown.

After this group had gone some distance there came behind it a collection of similar stars, some with long tails, some with short tails. They moved in regular form straight across the sky, and disappeared in the south.

Dresden (159 Miles, W. 27° S.).

Jno. A. McVean.

The course was about midway between the horizon and the sky in the north towards the south-east.

When I first turned to look there was one that broke into four pieces, each piece having a separate tail. The color was that of fire. This one seemed to be visible for nearly a minute. The four pieces seemed to keep together. There were two others that had tails similar to these, but they remained intact throughout their course. Then seven or eight more followed, having no tails at all, and of a different color, more that of stars—a blue white.

The first four were just passing from sight when the second one (with a tail) was about midway in the sky, and the other with a tail followed at about the same distance, and then the ones without tails came very close to one another, about three times as close as the other. There were three or four of the latter in sight at one time.

Duration, about 5 or 6 minutes. No sounds heard.

Dunnville (53 miles, S. 13° W.).

Wm. H. Sharp, B.A., reports that a gentleman gave him the following particulars: The meteors passed directly overhead, were travelling due east-south-east, were about 100 in number. The display lasted about three minutes, and the sound was heard just after they had disappeared.

Wm. Wingfield.

Estimated that the meteors passed about 10° south-west of the zenith.

Dutton (127 miles, W. 32° S.).

Miss Isobel O. Hally, B.A., reports that before being called to see the meteors the large first body had evidently passed. She saw a sequence of small, short, meteor-like appearances, moving in the same direction as the larger body—from north to south, perhaps slightly towards south-east. When facing slightly north of east the bodies in the middle part of their course appeared to be 45° above the horizon. They moved very slowly, several being visible at a time; then there was an interval of perhaps less than a second, and about half-a-dozen more appeared. These were short-tailed like the others, but whereas the others had appeared more in a body—two sometimes being parallel—these trailed one behind the other (two or three being visible at once) so slowly that each was easily visible several seconds. No sound was heard. All that was seen passed in about a minute.

Edgar (57 miles, N. 8° W.).

George B. Jamieson, M.D.

The meteors seemed to come from a point west of northwest and they disappeared nearly at the south point. They travelled in horizontal lines ,and all had the same leisurely rate of motion. Their course was about 22½° or 30° above the horizon. They travelled either singly or in pairs, and when in pairs one was above the other. I think I saw only two with tails, and these two were travelling in a pair. The tails were composed of other distinct meteors, gradually diminishing in size and trailing off as a flare of light at the end.

Duration of display, probably not more than 1½ minutes, each meteor being visible 3 to 7 seconds.

I heard no noise, but a neighbor saw the display, and he says he heard a sound like thunder, and counted 14 bodies.

Elmvale (65 miles, N. 19° W.).

Joseph Drysdale.

The display lasted four or five minutes. The meteors seemed to go in groups of threes, with tails behind them. They seemed to be mid-way between the earth and the sky. [Elevation 45°.] No noise was heard.

Elora (52 miles, W. 3° N.).

WM. FAIRWEATHER.

From eyewitnesses the course seemed to be right overhead. There were hundreds of them, throwing off sparks, and several exploding with a loud noise. Many persons heard the noise and thought it thundered.

Falkenburg (Muskoka, 98 miles, N. 4° E.).

G. S. YEARSLEY.

The first meteor came out of the northwest, about as bright as the evening star. It had a tail, and after travelling across he sky, disappeared in the south-southeast. It was visible 2½ or 3 minutes. It was followed in about 1 minute by two more, not quite so large, and travelling faster. After them came about 20 bodies like stars, some of which disappeared before reaching the horizon. I heard no noise. Night clear; temperature —14° F.

Fenelon Falls, 1 mile E. of (68 miles, N. 30° E.)

WALTER H. STEVENSON.

I counted seven bright stars surrounded by light. The cluster occupied a space about the size of the sun. A reflection followed, which was about the length of the tail of Ursa Major [say 18°]. About the distance between the Pointers [say 6°] behind this appeared a bright white star, as clear, but a little smaller than Venus is now [mag. – 4]; then a few clusters reddish like the first, but not so bright, say five or six clusters. Spread out on a wider track, there might have been eight or nine clusters, but I suddenly found that the whole heavens, from the zenith to the horizon, was full of meteors. They may have extended to the east, but there was such a wonderful display in front of me I never thought of turning. (See Fig. 7.)

The advance meteors, the brightest, passed *slightly* nearer the horizon than the zenith [say, elevation 40°]. The duration, probably three minutes, more or less. They travelled no faster than a crow flies. There was absolute silence. The whole was wonderful, but the most wonderful was the lone star following the first cluster.

Half an hour previously (about 8.30, I had been waiting outside with my rig, and when the others came out, I *remarked* to them that there seemed to be meteors "in the air," as I had noticed flashes or point-like sparks at intervals, as from an emery-wheel, single sparks overhead, where Auriga and Perseus must have been at that time, but I don't think the display which followed had anything to do with them.

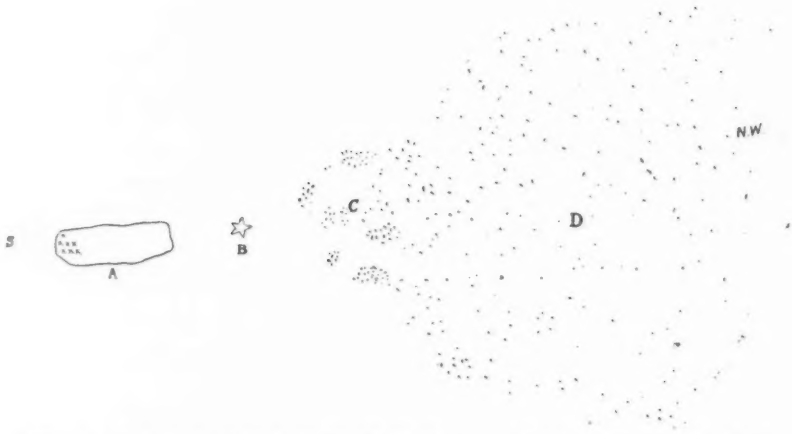


FIG. 7.—From a sketch made by Mr. W. H. Stevenson, Fenelon Falls. In the fore-part of *A* was a cluster of bright white stars; the rear was a reddish reflection, like glare from fire. *B*, a bright white star, of the size of Venus. *C*, reddish clusters. *D*, a shower of red meteors.

Fonthill (Welland Co., 46 miles, S. 10° E.).

ARTHUR GILBEY.

I saw several flashes reflected from the snow and seeming to come from the north. The sky being clouded in that direction, I could not see distinctly, but a few moments afterward I heard a rumbling, short and heavy, which I could not account for. I took no notice of it until a few seconds later I heard it again, and then for a third time. This was about 9.10 p.m. The rumbling was very plain.

Fort Frances (on Rainy Lake, midway between Ft. William and Winnipeg).

ROBERT MOORE, M.D.

Dr. Moore did not see the display, but on making his rounds in the Indian village near Fort Frances he obtained the following story from an Indian within 30 minutes after the phenomenon: "I saw them come slowly from the northwest; first, a string like candles, about forty of them; then, after 5 minutes, another string in the same line and about eight in number. They made the snow red quite a while after they had disappeared in the east. There was no sound, and they were lower than

the stars. They went slow. A big one led the first string. I am sure you will hear something. It must be the end of the world. It was about 9 p.m. They did not pass overhead, but north of us." (I think the time should be 8 p.m., C.S.T., and the Indian must have confused his directions. The course must have been south of the zenith—C.A.C.).

Fort William (W. end of Lake Superior).

JAS. A. UNDERHILL.

From observations made by Mr. Williamson, Gen. Sec. of the Y.M.C.A., and a young man who, with a party of snowshoers, was out in the open, the following information was obtained. Duration: quite a few minutes, 5 or 6, until it stopped. Direction: from N.W. by W. to S.E. by E. Middle of path about 30° S.W. of zenith. No sound heard. Number: perhaps 50, and many of them in sight at once. "A very amazing appearance."

Fox Point (Muskoka, 117 miles, N. 6° E.).

EDWARD A. BOOTHBY.

The meteors seemed to travel about 5° east of southeast, and the path appeared to be about 40° from the zenith.

Fullarton (91 miles, W. 8° S.).

FRED M. HAYNES.

The sky was somewhat clouded, but I saw the display coming from the north-west, but it disappeared under a cloud before half-way to the horizon. Probably the number would be from twelve to twenty, quite close together, without tails at all. Lasted not more than two or three minutes. Owing to small clouds in the sky, bodies were visible only when out from them. No noise whatever; bodies did not break up.

Georgetown (27 miles, W. 1° N.).

W. N. MCKAY.

The meteors travelled a little to the west of overhead, perhaps 60° from the horizon. They seemed to rise a little to the north of north-west. The first or leading meteor broke into pieces much like a Roman candle; of the others, some went right across the sky, and some disappeared while in flight.

Mr. McKay sent a clipping from the *Acton Free Press*, which, he thinks, describes very well their appearance. It says: "The phenomenon

witnessed was an irregular procession of luminous meteors as they traversed the sky from northwest to southeast. There were perhaps 15 or 20 meteors visible here. They were brilliant, fiery, luminous bodies, each bearing a tail after it, which disappeared in scintillations. A few seconds after the passing of the last meteor a series of explosions were distinctly heard, resembling peals of thunder."

Guelph (45 miles, W. 10° S.).

H. Westoby.

Though not fortunate enough to see the display himself, friends reported it to him at once. One gives the following: "About 20 or 30 lights appeared coming from the northwest by west, and shot across the sky, disappearing in the southeast. After the first lot had gone, some smaller ones appeared, following in apparently the same path and also disappearing in the southeast."

From a sketch which he was able to make, the path of the meteors appears to have been in the direction N. 57° W., and to have passed slightly to the northeast of the zenith.

Hepworth (109 miles, W. 38° N.).

Editor O. M. Seim, "Hepworth Progress."

A cluster of brilliant meteors, somewhat resembling the fireworks of the Toronto Exhibition, passed through the sky from northwest to southeast, going at perhaps half the speed at which single meteors usually travel. This bunch of meteors was followed by innumerable stars, going in the same direction. This kept up for nearly five minutes. We would judge about 100 stars went through the air in that short time.

Hespeler (50 miles, W. 18° S.).

William Foster.

The meteor started in the northwest, and when first noticed looked like a very high sky-rocket which was still going up. It travelled very fast towards us, and seemed to go right over our heads, or a little to the north.

In the display were many stars which seemed to start off with a jerk, and left a trail of light behind them. All travelled in the same direction, but some did not follow all the way. We noticed about two dozen or more.

A noise like a low rumble of thunder was heard after the display.

The following times were made out by going over the ground again, watch in hand. Time meteor was in view, 85 seconds; time stars were seen moving, 135 seconds; or total duration, 3 minutes 40 seconds. Time after end of display to noise of thunder, 50 seconds.

Hydro Glen (Muskoka, 85 miles, N. 2° W.)

NEAL McLEAN.

A large meteor appeared in the northwest, at an elevation of about 30°, with a long tail. When it was due south a second one appeared, not quite as large, and a trifle lower. They did not appear to come any nearer the earth, and the fragments thrown off seemed to continue after the main body.

There was no sound, and the display lasted about 3 minutes.

Islington (11 miles, W. 15° S.).

MRS. D. D. FRANKS.

In the northwest I noticed a luminous streak of light, much like the flame of a common oil lamp, interspersed with what appeared to be many stars. Its length seemed about twenty times its width. It moved compactly and comparatively slowly across the sky. A few seconds later another meteor came into view, similar to the first, but shorter. Then a third appeared, still shorter, but just as bright and beautiful as the first, and followed in the path of the others. Smaller ones appeared; these shot up the sky for a short distance and disappeared. They were paler and more rapid in motion than the larger ones.

The display lasted perhaps 3 minutes. I did not hear any report. The large meteors were the most magnificent sight I have ever seen.

Jarvis (65 miles, S. 36° W.)

THOS. J. HICKS, B.A.

Beginning of display, 9.08 p.m. (watch usually accurate, but may have been 50 seconds fast). The bodies followed in such rapid succession that one could not count them. They followed one another in fives; then a pause, and five more shot across the sky. I counted some 40 in a space of perhaps 24 seconds. They continued passing for about 2 minutes. No noise. Tails not noticeable, and bodies seemed to remain whole.

Jackson (103 miles, W. 38° N.).

JOHN HEWITSON.

It was a cold, calm, starlit night. Suddenly, from the northwestern sky there appeared what looked like an immense ball of red fire coming towards us at a tremendous rate, with a long tail streaming behind it at what seemed not a very great height from the earth, in comparison to the height of the stars. The head seemed much larger than the full moon, very red, and the tails extended a considerable distance behind, with pieces of the tails dropping off from the head every little while, but following on behind in the mad race.

It passed nearly over our heads, but a litle to the southeast, and finally, instead of dipping below the horizon, it kept on its course in the sky towards the southeast at what seemed the same height from the earth, until it was lost in the distance.

We gazed afer it for some time, fairly spellbound, even after it was lost to view, and in a minute or two we saw some smaller ones coming from the same direction, one by one rushing after the big one in the same track, as if a mighty current were drawing them along. These last did not seem to have any tails.

We waited around a few minutes, but saw no more, but what seemed like heavy rolls of distant thunder sounded. We heard no noise until after the meteors had disappeared.

Keldon (54 miles, W. 35° N.).

WM. ANDERSON.

I felt a slight tremor in the floor, and shortly afterwards went outside, and after shutting the door, which faces north, I heard a rumbling noise, which reminded me of a slight earthquake shock that I once felt in Scotland. If the building had not intervened I should probably have seen the meteors passing southward.

I find that residents here heard three distinct reports at different times.

Kinmount (83 miles, N. 26° E.).

JAMES LYLE.

At times there were only 2 or 3 in sight; then there were 8 or 10; and at one time as many as 12. Duration, 5 minutes. Some two or three had tails, and others sparkled.

London (105 miles, W. 25° S.).

F. C. W. Ball and F. E. Weir (students in Engineering, University of Toronto).

The meteors appeared at intervals of 15 to 20 seconds. Color, reddish yellow. Their path passed about 15° east of the zenith. The first bodies were single, but the last four appeared in pairs, of which the last pair were fainter than the others. No noise was heard, either during or after the display.

Rev. R. J. Bowen.

Observed the meteors from a point four miles east of London. At 9.12 p.m. I noticed a glare of light in the sky, moving slowly in a southeasterly direction. It then exploded like a sky-rocket and broke into about thirty or more meteors, each having a tail one-third to one-thirtieth as long as the tail of the original body. I heard no noise whatever, and this large display was visible to me for two or three minutes. It moved very slowly, and was well overhead. Had to put down the top of the buggy to get a better view.

While this large group of meteors were in view, the phenomenon developed and assumed great dimensions, for dozens of meteors came into vision. They were quite plain, but not nearly so brilliant, and had tails which seemed to be drawn after them and in the same direction as the large bunch of meteors seen first. By this time we had turned the horse and we were scanning the heavens to the northward, and suddenly a movement commenced, and I am not exaggerating when I say hundreds of tailless meteors moved slowly across the sky. These were not nearly so bright as the former ones mentioned. The impression it left upon me was the instability of the whole.

I have seen meteoric displays and phenomena in the Arctic regions and all over Western Canada, but never have I been so privileged to see so many heavenly bodies moving at one time, or any moving so slowly or in so low an altitude.

Mr. Bowen states further that his watch is usually pretty accurate and is never allowed to get more than two or three minutes fast.

Magnetawan (Parry Sound, 139 miles, N. 4° W.).

Donald Ross.

The meteors travelled from northwest in a direction south by east, and about 20° above the horizon. I saw about 20. Their motion

was not like that of shooting stars; much slower, four or five being seen at a time, and each being in sight about 30 seconds. The duration of the entire phenomenon would be close to 3 minutes.

They were round, with a tail to each, a fraction of a degree long; and appeared to emit sparks from each side as they sped along. About 30 seconds after the smaller ones (which were all of a size) had passed, a much larger ball of light apeared, white like the others, and with the same and in the same direction, but without any tail. When about midway horizon to horizon it burst and sent forth a shower of sparks, much like a rocket, and for a second it brightened the sky. I did not hear any sound.

Marshall, Mich. (100 miles W. of Detroit).

Fred. Cavanagh, of Oakville, sent a clipping from the Marshall *Chronicle* of February 10, 1913, containing the following: "Miss Vera Murray and Carl Schnaitman spent Sunday at Warren Clark's, in Fredonia, and when returning to the city last evening they saw two enormous meteors, with tails many miles in length. This happened shortly after 8.00 o'clock, and when Miss Murray and Mr. Schnaitman reached the city they reported that they had seen an airship going east. The heavens were brilliantly illuminated, and with the passage of the meteors a shower of stones was seen to fall. The display lasted for many minutes."

Melrose (Hastings Co., 113 miles, E. 20° N.).

H. O. Laufear.

The meteors seemed to come from a point almost due west, or slightly north of west, and not far above the horizon. The first one had a short tail, which looked dull to me, and it was quickly followed by 8 or 10 others, most of which had no tails at all. Duration, probably not more than 15 to 30 seconds; all in sight at one time. The middle one apparently burst into a number of pieces, but I heard no sound.

Midland (77 miles, N. 16° W.).

Rev. J. J. Elliott, B.A.

Did not see the display himself, but from eyewitnesses he learns the following: The brightest part of the spectacle was the leading group of four or five, travelling close together, and each leaving a trail of light of considerable length. About a minute afterwards there was another

and then others, until about fifteen in all were seen. No sound was heard. The direction was from northwest to southeast. The altitude was not high, and the meteors moved at a comparatively low speed.

Midhurst (58 miles, N. 13° W.).

R. D. Coutts.

So far as I remember, a large meteor was in the lead, although I think the largest of all led a group some distance behind the first. Both those and a few others had tails, although the most of them had not. Those were followed by still others, growing fewer and dimmer, the last I saw being scarcely visible.

They appeared to be going at the same speed, the paths being nearly level, as if unaffected by gravity, and they were travelling south by east.

Duration, about 5 minutes. Number of bodies, possibly 15 or 20 large ones, and quite as many or more small ones.

Mill Bridge (Hastings Co., 115 miles, E. 37° N.).

E. A. Norman.

I had just gone to feed my horse for the night, and as I opened a stable door at the southeast corner of the barn the first meteor flashed past the eave of the roof at the far end, or southwest corner of the barn. I went over this evening and took measurements. The barn is 50 feet long, and from my head to the eave of the roof is 20 feet; therefore the first meteor would be on an incline of 20 feet in 50, or 22° above the horizon.

Some of the meteors were higher and some lower. Two in particular, which travelled together, were one about three times the diameter of the moon above the other. I think there were about 12 or 14 in all. I think the leader was the largest, and was about half the diameter of the moon. They appeared to move quite slowly. They were about west when I first saw them, and about south when they got out of my range of vision. The new moon had set, and the large evening star was within 15 minutes of setting.

I heard no noises whatever. Sparks seemed to fly out from them, especially the leader, and smaller things like ordinary stars seemed to be darting about in their train. The leader was like a red ball of fire seen through a mist.

Milliken (12 miles, N. 17° E.).

ALEX. MACKLIN.

I had just gone out to view the heavens, as I often do on a clear night, when my eye was attracted by a gleam of light, followed by a group of about 7 of the fire-balls. They went from north-northwest to south-southeast, and the elevation was about 50°. These were quickly followed by several very bright ones, and numerous small ones, all following in the same plane. I should judge 15 or 20 in all, and not appearing to move swiftly as meteors generally do.

The largest of the fire-balls appeared almost white on the front, and seemed to be giving off sparks which quickly faded out, but a luminous tail was left to trace their path. They all had long, tapering tails.

Duration, probably 3 or 4 minutes. Two or 3 minutes after a rumbling noise like distant thunder was heard, repeated three or four times.

What struck me most was their comparative closeness, and when the sound was heard I could not but associate it with the display. All was over by 9.12, noted on an accurate clock.

Mortlach, Sask. (65 miles W. of Regina).

JNO. R. SMITH.

The time was somewhere between 7.06 and 7.15 p.m. (Mountain Time). I did not attempt to count them, but I imagine there must have been hundreds of them. They did not appear to me to be on a downward course, but on more of a straight line from west to east. I could not say how long they were visible, as I probably did not see the first of them. What impressed me more than anything else was that very few resembled shooting stars, only some of them having the tail or streamer behind them.

Mt. Charles (13 miles, W. 12° N.).

MRS. T. AIKINS.

Meteors passed directly overhead. The heads were large and luminous, tinged with red and supplied with tails which seemed to have from four to seven glittering particles behind them, a short distance apart. The space between was bright and white-looking. They came into sight and went out of sight like a flock of birds. They lasted for 5 minutes or more, and were followed by a rumbling noise like an explosion; and a second or two later was another not quite so loud.

Mount Forest (69 miles, W. 18° N.).

The Mount Forest *Confederate* says: A loud noise like that of thunder was heard here on Sunday evening, shortly after 9.00 o'clock. Some who were out walking at the time thought it was thunder; others thought it was ice cracking in the river; still others, that horses were kicking in a stable.

Muncey (116 miles, W. 28° S.).

JOHN STEWART.

The writer had a splendid view of the display. Position in sky, about 30° from point overhead. They were going about directly east and did not appear to be getting any nearer the earth. There were probably about 18 or 20 in all, about 6 or 7 being visible at once. Lasted about 2 minutes altogether. Heard no sound of any kind. Two had tails. About one-half remained intact; the others broke up—some more, some less. Each body remained in sight perhaps 30 or 40 seconds.

New York City.

MRS. MARGARET GRIFFITHS, of Watchung, N.J., 22 miles West of New York City.

I was returning from church with a party of friends, and was walking northwards; and the meteors passed directly over my head. We all had to hold our heads away back to see them. There were seven distinct meteors, or balls of fire, as they appeared to us, and two of them burst just as a sky-rocket does.

Niagara-on-the-Lake (31 miles, S. 30° E.).

A correspondent writes: "As we saw nothing of the display, I can only tell you of the sound, which was similar to the starting of a heavy wagon, and gradually dying away. There was also a slight vibration, which made the windows rattle. It lasted 2 or 3 seconds.

Oakville, 7 miles N. of (17 miles, W. 26° S.).

FRED CAVANAGH.

I distinctly heard the noise, like the rumble of thunder, coming from the north, and in a few seconds another less distinct.

Orangeville (40 miles, W. 29° N.).

MR. ALEX. STEELE, B.A., Principal of the High School, at the writer's request, made inquiries in Orangeville, and found two who saw

the meteors, but several who heard sounds which were pretty evidently produced by the meteors. These were compared to the rumbling caused on taking a carriage out of a stable.

Orillia (64 miles, N. 3° E.).

MISS ADELAIDE KING.

First seen in northwest about half-way between horizon and zenith. There were about 30 stars in all, divided into four groups. In the first group were about a dozen very large, bright stars, with a long tail resembling a large sky-rocket. Following this were three smaller groups (three stars in each) less bright, with no tails; and ending up were a few single stars.

Duration, about 5 minutes; largest body seen for 2 or 3 minutes. No sound.

MRS. C. E. GRANT.

I noticed a bright object suddenly appear in the western sky. It seemed at first like a shooting star, but instead of descending, or growing fainter, it appeared to move towards me and grow brighter, until it seemed to be quite close and not very high. It resembled a very large sky-rocket in brilliancy, shape and length, but instead of the bright balls at the head scattering and disappearing, the whole body retained the same form as it moved along in a stately way, going in a southeasterly direction and becoming less bright. But before this one was out of sight another one appeared from the same direction, quite as brilliant and as large as the first one, but the bright balls at the head seemed larger and not so numerous. It followed in the same direction, but had only passed when a group of three appeared, one above the other, not nearly as large or bright, with the tails rather separated. Then followed quickly another group of three, and immediately after two, then two more, then one, becoming less brilliant, much smaller and more detached, more like single bright stars, moving in the same direction, keeping the same position and form until lost in the distance.

No sound was heard. Duration less than five minutes.

Painswick (48 miles, N. 15° W.).

S. BLACKMORE.

There were about 12 meteors, and I watched them about five minutes. The first five or six were quite close together, the rest follow-

ing like a flock of wild geese and with about the same speed. Some left tails almost like a sky-rocket, others were like moving stars. The course seemed to be about 30° above the horizon.

Parry Sound (120 miles, N. 12° W.).

WALTER L. HAIGHT.

On the evening in question I happened to be returning from a snowshoe tramp, and was in the act of tightening up the straps on my foot when my companion called out: "Look! Look!" and I immediately threw my head up and caught sight of the large meteor, which appeared to be travelling very slowly—so slowly that the stateliness of its motion excited my liveliest surprise and wonderment. I have seen many meteors while out boating and walking at night, and many larger and more brilliant than the one in question; but this was markedly different from the rest in two main features, viz., that it was not so luminous, being of a distinctly reddish color, and that it moved with unprecedented slowness on a level plane.

As will be seen and noted on the rough sketch (Fig. 8), it moved at an elevation of from 35° to 38°, fixed by my companion and myself after going back and determining its position from our point of view.

The meteor was in two distinct portions, the head being round,

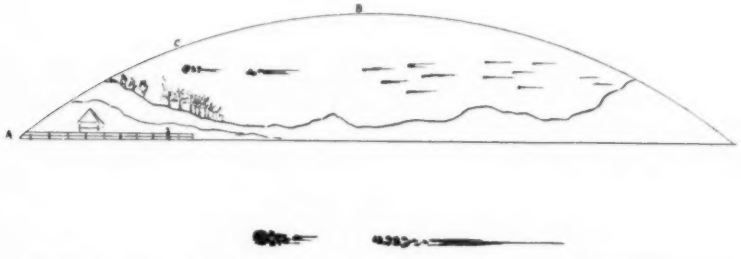


FIG. 8.—From a sketch by Mr. Walter L. Haight, Parry Sound. The observer is seen in the left fore-ground and the hill is shown behind which the large meteor disappeared. In the rear are shown meteors,—a group of four or possibly five; and, separated by a larger interval, another group of four or five; followed by a few scattered ones, bringing the number up to perhaps 14. *A* is the horizon, *B* the zenith and *C* is midway between *A* and *B*. The separate drawing below roughly shows the appearance of the large meteor. It is given mainly to illustrate the split between the head and the tail.

with fragments grouped about it and separated from the other portion by a short distance, and my somewhat dimmer recollection is that the rear portion was composed of globular masses, smaller and fainter than the head, and fading into a streak of dull reddish fire.

While my gaze was riveted on the large body, and just when it was about passing out of sight, my companion again called out, "Look! There and there!" and I looked up and saw the first group of following meteoric bodies, some five in number, I believe, loking like spent rocket-sticks when they first begin to move downwards—like them in the dull red of their glow and the slowness of their motion. They all appeared to be moving on a level plane and grouped approximately as in sketch.

Before I could recover from my astonishment, a new group of smaller ones, computed at four or five, came sailing along, followed by others more widely separated, and making a total of from ten to fourteen.

Possibly the flight occupied one and a half to two minutes. They moved from about west by north to east by south. I took out my watch when the flight passed, and it was 9.10.

I likened them at the time, and the resemblance seems yet apt and appropriate, to a large battleship moving ahead with attendant squadrons of torpedo-destroyers and torpedo boats. Never have I seen bodies in the heavens move at such a slow, stately and measured pace. That remains the most outstanding and remarkable feature of a most entrancing spectacle.

'Pon my word, I don't think I would have been more surprised had they swung about and sailed back into the west from which they sprung.

ASAHEL WRIGHT.

The series of lights travelled in unison and so horizontal that I could think only of a gigantic flying machine. The lights were at different points, one in front, one farther back, and a rear light, then a succession of small lights in the tail.

Pefferlaw (47 miles, N. 10° E.).

W. J. BOYNTON, M.D.

First, was a cluster of bodies moving rapidly to the southeast. These soon disappeared, but others followed in quick succession. They all came into sight from the northwest at about 45° from the horizon and disappeared about the same elevation in the southeast. Each body

took about 20 seconds to travel this distance, that is, half-way across the sky.

Probably 20 were visible at one time at the beginning. They were more numerous then, and became fewer at last until the last one was a considerable distance behind.

The display as a whole might be compared to an arrow, one bar ahead and many others following, and extending a considerable distance out at each side. I should judge there were between 50 and 100 bodies in all. The time of the display was close to 2½ minutes, estimated from the distance travelled, and my rate, which I know pretty well.

The bodies themselves were like red-hot missiles or shafts flying through the air. There was no luminous stream or tail like the tail of a comet, but they were both surrounded and followed by myriads of sparks resembling the fixed stars. These extended out a considerable distance from the sides, completely filled up the spaces between the different shafts, and followed the last one for some distance.

There was no sound. The bodies passed nearly overhead—10° or 15° to the west of the zenith.

Pense, Sask. (17 miles W. of Regina).

Messrs. G. and B. Spring Rice, when sending a report to the Agent of the Meteorological Service at Moose Jaw, make reference to the meteors, as follows:

I would call your attention to a curious phenomenon observed on the night of February 9th (Sunday). It was observed at about 7 o'clock (Mountain Time) in the evening, and I have called it a procession of stars. The first two stars were followed by a long tail, much like a falling star, but moved comparatively slowly in the sky, directly overhead, in a direction from west to east. These were followed by a number of other stars, sometimes singly and sometimes in groups, all of which moved across the sky at the same deliberate pace and in the same course. The procession must have lasted about two minutes. . . . . I have never seen anything like it before.

Peterborough (69 miles, E. 41° N.).

Rev. W. E. Hassard, B.A., B.D.

The appearance was like that of an express train lighted up at night. The elevation was about 25°. Movement was slow and the duration about 3 minutes. In the first section there seemed to be from six to nine lights, with slightly spreading ends. Then, in succession, some

three or four, not so brilliant sections passed. The most striking feature to me was the regular movement in an even plane. There appeared to be no curve whatever. No noise was heard. It was the grandest display I have ever seen.

Picton (114 miles, E. 12° N.).

E. M. Bigg, M.A.

A pupil of the Picton High School states that he saw the meteors nearly due west. About 20 in number and about 25° above the horizon

Port Hope (57 miles, E. 20° N.).

Mrs. Margaret Ketchum.

We stood under a west verandah and the procession of fire-colored globular stars seemed to come from the north-northwest, sailing over to south-southeast. The elevation was about 40°. We thought there were at least 25 stars. All had tails of the color of fire, a dull red.

Port Sydney (Muskoka, 105 miles, N. 2° W.).

A correspondent writes:

The first meteor resembled a kite with a remarkably long tail. They were decidedly low down and rather to the west. At least 10 or 12 bodies were seen, each one following close to the tail of the one before. Duration, not more than 3 minutes; no sound heard.

Richard's Landing (St. Joseph's I, Algoma, 287 miles, W. 40° N.).

J. H. Allan.

The meteors travelled from a little north of west, ending up a little south of east. When first seen their elevation was about 45°, and they did not appear to pass directly overhead, but about 22½° o the south of the zenith. In all, there must have been between 50 and 60, as many as 10 or 12 being seen at once.

Duration of display, about 2 minutes. No sound was heard. The bodies remained intact. One was considerably larger than the rest. Two or three had tails. Several remained in sight from 6 to 8 seconds. The color was that of a bright fire, not the clear white color of the average meteor.

Ridgeway (55 miles, S. 17° E.).

Rev. S. A. Laidman, M.A., Ph.D.

Three members of a troop of "Scouts" reported having seen the meteors. One large ball was seen first, about the size of the full moon,

and it was followed by about one hundred of the size of the brightest stars. These last all appeared at about the same time, and were not widely scattered. No tails noticed, but larger one was elongated.

There was a noise like rumbling thunder, which gradually increased in volume, then decreased again.

Rodney (139 miles, W. 32° S.).

JOHN A. CUNNINGHAM.

The meteors appeared in the northeastern part of the sky, halfway between the horizon and the point directly overhead. They travelled slowly from northwest to southeast. There were about thirty in all, and the largest number I saw at one time was five.

The bodies remained intact and the majority of them had tails more or less brilliant. One meteor at the close of the display was very bright and had a long tail. The phenomenon lasted three or four minutes, and the longest one body was in sight would be about ten seconds.

I did not hear any sound; if there was any I think I would have heard it, for I was in the country, where all was quiet.

Rothsay (65 miles, W. 9° N.).

The correspondent from Rothsay to the *Drayton Advocate*:

We did not witness the meteors last Sunday night, but we heard a noise like thunder, and felt a distinct shock as if an earthquake had taken place.

Rydal Bank (Algoma, 292 miles, W. 44° N.).

JOS. E. ASAM.

The first meteor at first appeared to be of the size and color of a large star, growing as it advanced. There was a tail of a red, shadowy appearance, which also grew in size and deepened in color. A little further on to the east it seemed to explode, much like a sky-rocket, throwing out a dozen or more balls.

This was followed by a second meteor somewhat smaller, travelling slightly higher. Then came a group of 15 to 20 travelling together and rather higher than the two preceding. Then followed a group, still higher, but travelling in the same course, and after this followed a group in the same course, only still higher.

In all, I would say there were about 40. They looked to pass about

one mile south and at an elevation of about 300 feet. (That would be 3° 16′ above the horizon.—C. A. C.)

The bodies appeared to travel almost east, with a downward tendency. The first was in sight about 1½ minutes, and I think it had disappeared when the last group came in sight.

St. Davids (36 miles, S. 20° E.).

REV. G. MUNRO.

I saw no display. . . . I was somewhat startled by a thunder-like sound. It seemed to come from almost directly overhead, or a little to the west. The sound was of the deep tone of distant thunder, but explosive rather than rolling. There was a rapid succession of distinctly explosive sounds, such as one hears in a quarry sometimes when a whole series of deep charges are exploded.

I gazed intently into the heavens all the while, but saw nothing. The time was approximately 9.15, and the duration of the sound perhaps somewhat more than half a minute. Others in the neighborhod heard the sound, but none saw the display. Some of them estimate the duration of the sound as much as 2 minutes.

St. Thomas (109 miles, W. 32° S.).

HARRY WILKINSON (age 12 years).

I saw about fifty meteors. At first there came about three, then about seven, and then they kept on coming in large clusers till they all passed. Some had sparks shooting from them, and same had tails more like comets. They were travelling from northwest to southeast. They looked like sky-rockets, only they did not fall.

Sand Hill (26 miles, W. 33° N.).

MRS. D. TIGHE.

Some had tails and some seemed to shoot a red vapor which threw a beautiful red glow. They came in bunches or groups. I counted ten in one group and I think there were 20 groups. As they disappeared in the east there was a loud report like rolling thunder, and then another sound like thunder, and a tremor of the earth.

Shelburne (49 miles, W. 37° N.).

R. A. RIKY states that a man who lives four miles east of Shelburne reported to him on Monday morning that there must have been

an earthquake the night before, that the vibration was quite perceptible, and the noise was like a series of blasts going off.

In the Shelburne *Economist* it is stated that a man living 12 miles west of the town was awakened from sleep and thought that his horses were wrecking the stable. On investigating, however, he found the horses perfectly quiet.

Sheridan (17 miles, W. 36° S.).

H. A. Leamon.

The path of the meteors passed about 15° southwest of the zenith.

As the first meteor got higher in the sky and nearer me, I saw it had an immense tail which seemed to have very bright litle sparks in it from one end to the other. Those at the head were larger than the others, but not a bit brighter. As it got nearer the ball of fire seemed to break up, and as nearly as I could count there were 17 more with little tails. Then again, somewhere between 50 and 100 individual sparks appeared, as if they shot off the main body when it broke, or seemed to break.

Long after the main body had passed and was fast disappearing in the southeast, I saw tiny sparks just whizz by, seemingly endeavoring to catch up with the big fellow which had left them behind.

The whole display must have lasted 4 minutes, and just after the first disappeared in the southeast I heard a rumbling. The main body must have been in sight 2 to 2½ minutes.

Springbrooke, 3 miles west of Brampton (19 miles, W. 7° N.).

J. P. Henshaw.

Commencement of display, 9.05, taken on a watch correct to a few seconds. The bodies had tails. The first was the biggest, and it looked as if the others all came from it and naturally had shorter tails. There must have been at least 60 bodies. Sound was heard in the midst of the occurrence, like a rig going over a bridge.

Springville (65 miles, E. 42° N.).

Rev. D. B. Marsh, F.R.A.S.

As the congregation was leaving the church after the Young People's meeting, Mr. F. E. Wilson called me to the door, which faces west. I immediately saw a large red meteor, followed by others, coming from the northwest. I looked at my watch; the time was 9.04½. The forward meteor was very large and very red, with the tail several de-

grees in length. Those following were irregular in size, some in pairs and others following lazily along the sky. The head of the large meteor was eclipsed for a moment by the top of a telephone pole, so placed that the line adjoining it to the observer made an angle of 49° with the meridian. Afterwards I set up a transit instrument to represent my position, and sighted the top of the telephone pole, which gave me an elevation of 14° 58′ above the horizon.

After looking upon the grand spectacle for (say) 2 minutes, I counted 10 meteors in all. (Some of the people say they counted more.) I then ran into my house adjoining the church and got out a 3-inch telescope, but the last body had vanished. Some of these meteors passed on to the southeastward out of view, while some burned out and vanished before our vision. I believe there was no noise heard by anyone. Their duration was about 3½ to 4 minutes.

Stouffville (23 miles, N. 16° E.).

Miss Gertrude Kendrick.

The first meteor was funnel-shaped; it was small at first, but grew larger as it passed from about half-way up from the horizon in the northwest to about half-way down to the horizon in the southeast. I saw about 8 meteors, the first being the largest, and the ones following being each a little smaller than its predecessor. The bodies did not break up, and each had a tail. Duration, about 2 minutes; and the first one was in sight almost the entire time. It had just nicely disappeared before the last one came to view.

Sturgeon Falls (186 miles, N. 6° W.).

The North Bay *Times* states that there was a mysterious visitor to Sturgeon Falls on Sunday night, when several citizens were surprised to see a slow-moving object in the air a short distance from the earth. The meteor resembled a large aeroplane or dirigible, with two tiers of lights strung along the sides, and moved slowly toward Lake Nipissing.

Sudbury (Nipissing, 214 miles, N. 9° W.).

W. J. Bell.

The meteors were seen close to the southern horizon, and the duration was about 30 seconds. The number of meteors counted in the first place was 5, all of which exploded into parts of two to six each, and all had tails. These were observed from the street, and the view to the south was somewhat obstructed by a hill, which may possibly have hidden some of the meteors.

Sunderland (45 miles, N. 23° E.).

JOSEPH PURVIS.

In the first lot there were about ten, and two of them, which were quite close together, were much larger than the rest. The whole cluster was as wide as the distance between the points of the moon on Sunday night. There was a bright red light all around them, with a more distinct light behind as they travelled along.

There were four distinct clusters. The first, of about ten; the second, of about three; the next, two; the fourth, one—this one having the size of a bright star. All visible at one time. First cluster visible to me about 1½ to 2 minutes; it disappeared behind a building. No sound heard.

Thamesville (151 miles, W. 29° S.).

MISS CATHARINE MACVICAR DUNCAN.

The sky was not so bright as on the evening before; large areas of the sky were in misty darkness. Suddenly, right under Cassiopeia, travelling from northwest to southeast in a horizontal plane and *very* slowly, almost as if it were stopping or just going to dissolve in air (*not* drop), appeared the Head Light. It glowed now brighter, now duller, and it looked like a parallel trail of dozens or perhaps hundreds of distinct stars or sparks, that either went out or fell behind (*not* down). My brother shouted to me, "An air-ship!" And I said, "Mrs. M——'s chimney is on fire." It loooked that near. (This house was about 70 feet away, and obscured behind spruce trees.) The big leader seemed to curve a little to the south, but those that almost immediately appeared, one at a time, seemed to follow exactly in his path. It was a slow procession, not more than three or four being seen at one time. It reminded me of a dozen fish swimming at intervals, and one after the other.

To the eye they were little above the housetops. There might have

FIG. 9.—From a sketch by Miss Catharine MacVicar Duncan, Thamesville. There were hundreds of sparks in group No. 1, dozens in No. 2, fewer in the followers. No. 5 was a big one floating along by himself. Each group was distinct and separated from the others. There might have been 12 of them, but no more. The last ones were very dim, like luminous gas.

been 12 groups of bodies, but no more. I am sure of 8. In the first there were hundreds of following sparks; dozens in the second; fewer in the rest. One big body floated along by himself after about the fourth group. Each group was distinct and separated from the others. The last ones were very dim, like luminous gas, fluttering now brighter, now dimmer. (Fig. 9.)

The phenomenon lasted three or four minutes, perhaps longer. We had to get to the south side of the street the better to see them. No sounds were heard. The big leader was in sight longest, over a minute, I should say.

TORONTO

Sydenham and Parliament Sts.

H. D. Ashley, of the Toronto Police Force.

The meteors were observed in company with Sergt. Lydiatt. The first meteor was by far the most brilliant of all, had the general appearance of a chain of fire-balls decreasing in size and followed by a pale beam of light not unlike that of a large searchlight.

It was followed by five others, not nearly so luminous. I counted 16 in all, the last 4 being extremely dim. Indeed two of these were seen to rise in the northwest, but became entirely invisible before passing over. Duration of entire display, 340 seconds.

Cecil and Bathurst Sts.

W. A. Barber (University Student in Mathematics.)

There were 17 or 18 meteors, and the color was reddish. The course was about 60° above the horizon. All had long tails, perhaps 30° long. The head of the meteors seemed to break up. Diameter not greater than 2'. Heard sound like thunder about 1 minute after last had gone.

St. Clair Ave., near Oakwood School.

W. Betts.

There were about as many as shown in the diagram (Fig. 10), and the display lasted from 5 to 8 minutes. The bodies remained as shown in the diagram. Any one body was in sight about 30 seconds.

FIG. 10.—From a sketch by Mr. W. Betts, Toronto. The front meteors were very brilliant and appeared to be like fireworks on the point of exploding, the heads appearing like golden balls. Those next following were less brilliant although very bright. They gradually diminished but looked like remnants of fireworks or like stars flying through space—all at the same speed. The meteors appeared far more scattered than represented above. (See note to Fig. 5).

Parkdale.

JOHN BUTTERFIELD.

We heard a heavy rumbling noise, but the sky was clear. There was a short interval of silence, and then a rumbling and a noise like thunder. The time was observed on a watch afterwards tested and found to be correct, and was 9.12. It reminded me of an earthquake I heard in September, 1910, near Cobalt, Ont.

Bedford Rd., near Lowther Ave.

MISS BOYD.

The bodies went in regular procession, travelling quite slowly. After all the rest had gone a single one appeared. Sounds like cannon were heard as the lights disappeared, four or five rumbling sounds, very distinct, but not continuous. They were heard by Mrs. Boyd in the house.

Roxborough St., near Yonge St.

HERBERT E. BROWN.

One meteor appeared first, then another of about the same size (the first leading by a short distance), then closely following the second were six somewhat smaller ones, travelling two-by-two, and the rest came close behind these in irregular order, about fifteen in all. I tried to count them, but owing to questions from my companions and the awful majesty of it all, I lost the count. The first two broke into many pieces and left a trail of fire in their wake. Duration of display, about

3 minutes. From the time the first one struck the atmosphere until it passed out it was about a half-minute. A noise like distant thunder was heard.

Kenilworth Cres.

E. CHEETHAM.

There were 21 meteors. The first was a very large one; then came three more, nearly as large and very bright. Then came two more, but smaller; then four and three and two, until they got like sparks in the sky. After the last meteor had passed there was a rumble like thunder, which I spoke of at the time, as the night was very cold.

Moore Park.

JOHN CLARK.

In the first group were three bodies, two abreast and the third below the others. Each of these three had a long tail. Then came a pair, and then other bodies not so bright and without tails. One of these in particular was very noticeable, having a kind of quivering motion. After this were two more bright ones, like the first pair of bright ones, and then after this a shower of sparks was seen in the northwest where the meteors had come from. These were much like sparks blown from a chimney. They did not pass over like the meteors, or if they did come they were not visible to us.

The whole lasted about 4 minutes, and the path was about 40° above the horizon. Heard no sound.

Robert St., near Russell St.

WM. R. EVANS.

In the first lot there were two, side by side. Then four or five followed singly, and then two came close together. The rest followed singly. The time between successive ones varied from 10 to 20 seconds, or not more than 3 minutes in all.

Deleware Ave., near Bloor St.

FRED M. FISHER.

The total number I counted was 22, and the entire flight, I judge, occupied about 1½ minutes. At one time possibly 10 were in view. The course passed about 30° southwest of the zenith.

Broadview Ave., near Bain Ave.

CHARLES FULLER.

The meteors came into sight right over the Swiss Cottage. (As seen from the corner of Broadview and Bain Avenues, this building is 27° N. of W.—C. A. C.)

I did not count them, but thought there were about 20, appearing like this:—

1—3—2—6—4—2—1—1.

The six in the middle formed a grand group, and they all kept regular formation all the time.

No noise was heard, and the duration of the entire display was about 4 minutes.

Gerrard St., near General Hospital.

W. H. GREGORY (University Student).

The shower, which consisted of some 18 meteors, seemed to appear in the north, a little to the west, and travelled across the sky to the south-east. They seemed to pass nearly overhead, about 5° from the zenith. Most of the meteors had streaming tails, and the first one broke up. The bodies travelled in groups of three, and the first were considerably brighter than the later ones.

Earlscourt, N. W. of the City.

EDWARD GURNEY.

The meteors came from a point about 5° west of Cassiopeia, and appeared to be about 45° above the western horizon.

Windermere Ave., Swansea.

MISS IDA HOWARD.

The path was about 60° above the horizon. The first group consisted of one large one leading two abreast. These were of about the same size and had tails, which appeared to be parts of the main body, breaking off like a rocket.

These were followed by about ten others, not quite so large and with smaller tails. Then after a few seconds there appeared a great number of small bodies following in the same direction as the first. They were all of a bright red color.

Duration, from 3 to 5 minutes. After the display had passed my two companions and I all heard a sound like two rolls of thunder.

Hepbourne St. and Dovercourt Rd.

E. C. HUNT.

The first meteor was the most brilliant of all; it was like a ball of fire, with a long tail. During its flight other bodies left it and followed in its tail. Then two more followed, but not quite so brilliant; these travelled abreast. Three others followed, just behind each other, two of which had tails breaking up in the flight, the third remaining intact. These were followed by a cluster of eight, not nearly so brilliant, only one having a tail. Nine more followed, remaining intact and being very dull. Altogether I counted 6 with tails and 17 without, 23 in all. They all passed in 4 minutes; no sound was heard.

Yonge St., near St. Michael's Cemetery.

E. KIRBY.

There were from 12 to 15 bodies, and they appeared to be travelling from west towards the east. They had the appearance of rockets, on account of the fiery tail. Duration, 2 or 3 minutes; after which there seemed to be two peals of thunder.

Balmoral Ave., near Avenue Rd.

A. T. LAING, B.A.Sc.

The bodies had streamers behind them which looked like ribbons of light, and they moved slowly and uniformly, as if all were drawn along by a cord. The course was horizontal, with no apparent downward tendency.

The width of their path was about 4° or 5° and they passed about 20° southwest of the zenith. The path, from the point where they were

FIG. 11.—From a sketch by Mr. A. T. Laing, B.A.Sc., Toronto. This represents about 90° of the flight.

first seen to that where they disappeared, subtended an angle to the eye of about 120°. The brightest bodies were visible about 30 seconds.

On the following Saturday, with the assistance of Prof. L. B. Stewart and a prismatic compass, an attempt was made to determine the direction of the course. By sighting on the beginning and the ending of the path it was found to be from about 26° north of west to the same distance south of east.

Don Valley, ¼ Mile N. of Bloor St.

J. G. MacArthur.

There were probably 30 or 32 bodies, and the peculiar thing about them was their moving in fours, threes and twos, abreast of one another, and so perfect was the lining up you would have thought it was an aerial fleet manoeuvring after rigid drilling.

About half of them had passed when an unusually large one hove in sight, fully ten times as large as the others.

Five or six would appear in two detachments, probably 5 seconds apart; then another wait of 5 or 10 seconds and another detachment would come into view. We could see each detachment for probably 20 or 25 seconds. The display lasted about 3 minutes.

As the last detachment vanished the booming as of thunder was heard—about 5 or 6 very pronounced reports. It sounded in the valley as if some of the balls of fire had dashed into Humber Bay. The bodies vanished in the southeast, but the booming appeared to come from the west or northwest, and the time it was heard was close to 9.12 p.m.

Pape Avenue.

E. McGill.

There would be a number of the bodies in a line with a light streak between them; and the last was one large ball by itself. The display lasted fully 3 minutes. While we were gazing with awe on the brilliant display far above us in the clear sky a voice from a group of men was heard to say: "Oh, boys, I'll tell you what it is—an aeroplane race."

It was 9.10 by my watch. About 3 minutes later we heard three reports like thunder, which seemed to come from the west.

Indian Rd. and Geoffrey St.

James G. McMillan, B.A.Sc.

The path of the meteors when passing appeared to have an elevation of about 30° above the horizon.

The tail of the first and those of some of the following ones extended to a considerable length, and looked not unlike the sheaf effect produced by certain rockets, except for the differences of direction. They would subtend an angle of perhaps 5°. At the end of the display several luminous balls appeared, travelling with a somewhat wavy motion and not in so direct a line as the larger meteors. I followed one of these, and

think I counted three others, which, except for their motion, were not readily distinguished from stars of a red color.

A sound was heard by some of our party after I had left them, which must have been about 1½ minutes after the last bodies had passed and nearly 4 minutes after the appearance of the first ones.

Bathurst and Dupont Sts.

CYRIL A. MOSS.

There were about 15 meteors, and all had long tails except the last, which was just like a star and came some time after the others. The first meteor broke into three parts, which all travelled together. Then there were two pairs and the rest were single ones.

Two sounds were heard, not just like thunder, but like immense upheavals in the earth some miles away. The first was louder than the second, and in the interval between I had walked two (short) blocks.

Brunswick and College Sts.

H. G. MURRAY (University Student in Mathematics).

Course from N. W. by N. (34° W. of N.), but could not see the beginning for houses; centre of path, about 45° above western horizon; width of stream, about 3°; color, golden yellow, like a sky-rocket but not so bright; a single body visible about 30 seconds. All had tails, which seemed to be lost as the bodies moved away, due to foreshortening. Duration, not greater than 5 minutes; no sound heard.

Queen's Park.

JOHN H. PARKER.

The first group seemed to number five. Then followed a group of three and after that four or five single ones. Heard a sound like distant thunder. The path seemed to be about 20° from the zenith.

Bloor St., near McMaster University.

N. S. ROBERTSON (University Student in Mathematics).

Beginning of display, 9.05 by watch. Duration, 1 minute or more. Saw small ones break off from larger ones. There were about 17 or 18 of them, 3 or 4 being seen at one time. There was usually a large mass followed by smaller ones. The path in the sky subtended about 1½ right angles. The elevation of the course of the meteors was about 55° above the southwest horizon, and on tracing the course on a city map it appeared to be from a point about 47° west of north.

Walter St. and Kingston Rd.

KENNETH SNYDER (age 12 years).

The meteors appeared to be a little west of overhead, travelling from northwest to southeast. I did not count them, but I judge there were twenty or more. They usually went in pairs, each pair being quite a distance behind the one next ahead of it. The whole phenomenon lasted about 3 minutes, each body being visible from 15 to 25 seconds. After the last ones had gone a dull sound like distant thunder was heard.

Near King and Jarvis Sts.

H. A. VAN WINCKEL.

The position in the sky of the first one seemed very low, so low that at first I thought it was a rocket. The succeeding ones seemed much higher. I should judge there were 15 bodies, or a few more. Some were single and some went in twos and threes. The first appeared to be the largest and most brilliant of all; and the phenomenon lasted, I would say, between 3 and 5 minutes.

The bodies broke up without exception and left a tail behind as they went through the sky. I would not consider that any of them were visible for more than 30 seconds, with a possible exception of the first, which seemed larger and brighter than the others.

Queen's Park.

DR. W. M. WUNDER.

There were about 25 bodies in all, and the centre of the path was about 25° southwest from the zenith.

Bloor St., near Robert St.

A CORRESPONDENT.

The meteors were fairly high up in the sky, but at no time overhead. About 15 or 20 bodies seen; duration, 3 or 4 minutes. About 3 minutes after the display was over a noise like thunder was heard—not very loud, but decidedly like thunder. The bodies remained intact. They had long tails and moved quite slowly. Some would be seen coming in the distance while others were disappearing. When all were gone two large stars with tails remained.

Poplar Plains Rd.

Mrs. Davis and Miss Florence Davis clearly observed the trembling

of the house and heard the noise, being especially impressed by the trembling.

Mr. J. C. Dempster (University student) and Rev. Professor Bowles of Victoria College also heard the sound and remarked it at the time.

Trenton (94 miles, E. 18° N.).

J. T. May.

We caught sight of a brilliant body in the western sky. At first glance I thought it a comet, of large proportions but of reddish color. We followed it, as it moved quickly in a southerly or south-southeasterly direction, for perhaps 1½ minutes, as it was growing fainter in the southeastern sky. Meantime others of smaller size came into view—five or six, followed closely by others, not in a string, but in about the same order as horses or men in a race, to the number of about twenty, over the same course. Altitude, about 25°. Time of visibility of the meteors, about 4 to 6 minutes.

Trout Creek (Parry Sound, 158 miles, N. 2° E.).

Rev. T. A. McComb.

I saw a cluster of brilliant stars, apparently 12 or 15, but no doubt there were more than that, sailing along in the sky, going almost south, probably a little southeast, followed by a train of light. Soon appeared a smaller cluster, not so brilliant, with a train of light; then another and another, each smaller and less brilliant; but all appeared to follow in the same course. They were on the western side of the town, low down towards the horizon.

In all there must have been 15 clusters, though the last ones appeared only as one star. The whole phenomenon lasted probably 3 or 4 minutes. No sound was heard.

The bodies remained intact and did not appear to move with great rapidity, but with steady horizontal motion. They reminded one of the motion of a railway train at night seen at a distance of 5 or 6 miles.

Udora (42 miles, N. 10° E.).

Mrs. Norman Harvey.

The meteors were seen in the west, about half-way to the zenith. They seemed to be going slowly from northwest to a little east of south. The first set was the brightest; it seemed very low down, as if it might

drop at any time, and there were dozens in it, some large and some small. There was one very large one, and the others were of various sizes. After that they came in great number, following after the first, for about five minutes. No noise was heard.

Unionville (15 miles, N. 16° E.).

ARTHUR E. STIVER.

First there were 5 large ones, then 2 small ones, then 1 with a tail on it, then 7 more. A sound like thunder was heard.

Walsh (80 miles, S. 40° W.).

GRANT BINGLEMAN.

Time, about 9.10 p.m. They came from the northwest and went southeast. The first was a large meteor, which went apparently quite fast. When nearing the southeast it burst, leaving many small meteors in the sky. Then followed small meteors, about twelve in number; these had but short tails.

The display lasted about two minutes in all. The first large meteor burst shortly before it vanished; the others remained intact. I heard no noise. Each meteor remained in view only a few seconds.

Warsaw (84 miles, E. 40° N.).

MRS. DAVID MILLER.

The meteors were in a belt about 10° or less in width, and the highest ones were about 35° or a little less above the horizon. About 20

FIG. 12.—From a sketch by Mrs. David Miller, Warsaw. This does not represent the number but it shows the style of the bodies and their motion. They had long, narrow, straight tails; one leader; one at last. The leader and a few others had disappeared before the last came in sight. They seemed to travel in a prescribed belt.

bodies; no sound heard. One seemed to me to stay in sight nearly two minutes, but this is uncertain.

They came along like a lot of fish distributed in a pond, straight and parallel. None had very big heads, and all had perfectly straight tails.

The first ones were quite white, the last ones very red. The last one seemed to be different; the head was a little larger and the tail seemed like a string of stars (Fig. 12).

Waterloo (58 miles, W. 11° S.).

E. D. CUNNINGHAM.

The first meteor seen was the largest. Its course was almost directly overhead, but a little to the east. It passed slowly across the heavens, disappearing in the southeast, taking fully 10 seconds to cross. It had a tail probably 10° in length. The course seemed to be from 30° west of north to 30° east of south.

The first one was followed by at least thirty others, the mgajority being a little to the east of us, with a few directly overhead, none to the west. Very few of these had any sign of a tail, the majority being simply bright bodies. Many did not cross the heavens, but disappeared when overhead.

The display lasted for about 2 minutes, from 1 to 5 meteors being constantly in view. After the meteors had disappeared fully 2 minutes elapsed before any unusual sound was heard, and then we distinctly heard, at intervals, a succession of explosions which could not be better described than by comparing them to the report of heavy guns heard from a distance.

Wexford (10 miles, E. 41° N.).

HUGH DOHERTY.

I looked southwest, and it was just one long stream coming from a northwest direction. I noticed the stars shining through the long line of fire which was moving along. We all heard the thunder; it fairly made the house shake, and we said there was another earthquake in Toronto.

Whitby (27 miles, E. 32° N.).

ALMOND RICHARDSON.

The first meteor was much the largest and possessed a much longer tail than the others. The rest of the collection were spread out on either side and behind the first, but all were going in the same direction and at the same speed. They gradually got smaller towards the last, but all had tails, the first ones being about four times as long as the last. About 30 bodies in all and about one-third of them in view at one time. Duration, about 2 minutes; no sound heard.

Winchester (222 miles, E. 27° N.).

Rev. R. H. Archer.

I saw two meteors at 9.10 p.m., approximately. They looked to be about ¼ mile in front of me, travelling in a southeast direction. The first I saw for about 15 seconds; the second, coming immediately after it, I saw for about half a minute. In that time it seemed to go about 150 yards. (This corresponds to an angular path of about 20°.) Estimated elevation about 15°.

Part II.

OTHER BRIGHT METEORS SEEN WITHIN A FEW HOURS OF THE GREAT DISPLAY

Brampton.

Mr. J. G. Beatty, a University student, reported that at about 8.20 p.m. (Sunday), while watching the bright planet Venus, he saw a bright meteor moving quite slowly, approximately from northwest to southeast.

Saranac Lake, N.Y.

F. W. O. Werry, B.A.

Venus and the moon were low down in the west. Between 7.30 and 7.45 I was facing the west by north. I saw a shooting star start about 10° higher up than Venus and move rapidly along a horizontal line (or nearly so) for about 30° and towards the north. In a few minutes another meteor started in the same region and shot across the same part of the heavens, though not reaching more than half its length.

Peterborough.

Walter Peters (Meteorological observer) did not see the display, but a reliable man reported to him as follows: "I was out Sunday evening between 9 and 10. Suddenly I noticed the snow illuminated brightly. My first thought was that someone's chimney was on fire. On looking up I saw a large ball of fire moving westerly. At this time it was distinctly overhead. It had begun some distance east of the zenith, for some time elapsed before I looked upward. It proceeded directly westward. It had the appearance of a large rocket. The "head" was of considerable size. Behind it there were perhaps a dozen smaller balls of fire. The spectacle was splendid. The ball did not go below the horizon. There was no explosion and no noise. It died out naturally."

Roblin (Lennox and Addington Co.).

GEO. H. BROOKS.

I had the good luck to observe the meteor. It was at 9.30 p.m., and appeared in the western sky, seeming to travel south or southwest and about 20° above the horizon as nearly as I could judge. There appeared to be an extra large ball ahead, then a dark space, followed by a long tail. The meteor did not appear very distinct to me, and for a short time disappeared. It was visible for fully half a minute.

Ann Arbor.

LEWIS L. MELLOR, of the Detroit Observatory, in *Popular Astronomy* for March:

On February 9, 1913, an exceedingly bright meteor was observed here at 10.15 p.m. C.S.T. It first appeared as a bright star in the neighborhood of β Cassiopeiæ; its position was approximately, $\alpha = 0h$, $\delta = + 58°$. It travelled in a path which if continued would have joined Saturn and β Cassiopeiæ, and a seemingly violent explosion occurred just before the Pleiades were reached. Simultaneously with the explosion came a flash of intense blue light, which was bright enough to illuminate the entire city of Ann Arbor for a fraction of a second. The disintegrated mass spread out into several hundred visible fragments, a few of which disappeared below the horizon before being completely consumed. At the time of the meteor's disruption its co-ordinates were approximately, $\alpha = 3h\ 30m$, $\delta = + 17°$. The minimum intensity greatly exceeded that of Venus, which is so conspicuous during the early evening; at the maximum the apparent size of the disc of the meteor appeared to be about one-fourth that of the moon, but its surface brightness greatly exceeded that of our satellite, for it emitted an intense white light resembling the magnesium flash.

The flight of the meteor occupied 5 or 6 seconds. Its continuous trail remained visible for the same length of time. As the meteor increased in apparent speed its path became irregular, following a zig-zag curve, and accompanying showers of sparks seem to indicate that it was revolving very rapidly on its axis. The features were so distinct that I estimated its distance to be about 75 miles west of Ann Arbor, although I did not hear the report of the explosion; in all probability this may be due to the fact that the wind was blowing from the southeast at the rate of 12 miles an hour.

Arthur (Wellington Co.).

J. J. Morrow, M.D.

When returning from a sick call, about 1.15 a.m., Monday (Feb. 10), I was surprised to notice the whole heavens light up. The condition lasted for 3 or 4 seconds. I was driving in a westerly direction and the light appeared to flash out of the northern heavens. I did not see any meteors or hear any sound.

Perm (Dufferin Co.).

T. H. Banks.

Time, 1.27 a.m. Monday, February 10th. A brilliant meteor in the north, travelling west. Body in sight about 12 seconds. When nearing the horizon it broke into many pieces, which died away in 2 or 3 seconds. Whole phenomenon lasted about 15 seconds. No sound heard.

Vittoria (Norfolk Co.).

Joseph A. Montrose.

When about four and one-half miles southwest of Vittoria, at about 1.30 a.m. (Monday) I saw a single meteor. It lasted about 3 seconds, in which time it lighted up the earth with a dazzling brightness. It was to the northward at an elevation of about 45°. It was travelling with a westward motion and coming down at an angle of about 53°, as nearly as I could guess. It had a long tail. I heard no sound.

Windsor.

Geo. A. Deane.

The meteor I saw was a remarkable one. I have seen one or two meteors in a rather long life, but never before one like this. In size it appeared about that of the full moon, but it was not round in form, being a long oval. The accompanying sketch (Fig. 13) I made next morning.

It was descending (apparently) directly to the earth. At first glance I took it for a collapsed balloon, but only for the instant, as I at once recognized it as a meteor. I expected to hear in a few days of some damage it had done at no great distance from here.

The outline was very clear and distinct, with no "rays" or "nebula," such as usually attend a very distant bright light.

The time was exactly 1.23 a.m. (Monday). I looked at my watch, as I fully expected to hear more of it. It was in the north-northeast. It

did not appear to me like a swiftly *falling* body, but appeared to travel toward the earth in a very slight curve.

In color it was the red of the setting sun, denser at the bottom (large end), running to a yellowish flame color at the top. Time body was in sight, I should judge about 1½ seconds.

Mr. F. P. Gavin, M.A., Principal of the Collegiate Institute, reports as follows:

Mr. A. W. Brown, of Windsor, railroad man, on Sunday evening, February 9, was left as watchman on a wrecked train on the C.P.R. about one mile west of North Newberry (just the other side of Bothwell).

Mr. Brown states that he was awake and observant all night and noticed the following: Some time about 9 o'clock he saw the largest meteor, bluish white, very bright, and travelling in a northeast to south-

Fig. 13.—From a sketch by Mr. George A. Deane, Windsor, of the meteor seen by him at 1.23 a.m., February 10th.

west direction. Again at about 2.20 a.m. he saw a series of meteors smaller than the one seen earlier, apparently following the same course, but visible somewhat longer, possibly 4 or 5 seconds each. There were about 18 or 20 of them and the whole display lasted about 20 minutes, sometimes several minutes elapsing between successive meteors. They appeared brightest about 70° to 80° above the horizon, and seemed to travel right down to the earth in the distance. Mr. Brown says he got the impression that they were heading towards Detroit from where he was stationed. This would give a west to southwesterly direction.

All the meteors seemed to have a stream behind them like a rocket, and brightened up the whole air. The large one in the early part of the evening was illuminating enough to attract the attention of one not watching. No sound was heard.

THE NEW REFLECTING TELESCOPE FOR THE DOMINION OBSERVATORY

By W. F. King

THE inadequacy of the instrumental equipment of the Dominion Astronomical Observatory has been felt for some time, and recently an effort was made to secure a larger reflector which happily has been successful. The Minister of the Interior has agreed to the purchase of a telescope with a mirror of at least 60 inches diameter (which, it is estimated, will cost about $50,000), and is willing to consider the purchase of a larger one, but before agreeing to a greater expenditure wishes to have more accurate information. We have sent out specifications to several makers in the United States and also to Sir Howard Grubb, of Dublin.

The sum of $10,000 has been voted by Parliament for preliminary expenses, which will cover cost of investigations as to the best place in Canada to erect the telescope, having regard to climatic conditions.

The specifications on which tenders have been invited are given herewith.

SPECIFICATIONS FOR LARGE REFLECTING TELESCOPE FOR DOMINION OBSERVATORY.

PRELIMINARY

1. Estimates shall be given to cover complete telescope of aperture 60 and 72 inches. The division of the cost between optical parts and mounting shall be indicated.

2. It shall be distinctly understood that material and workmanship are to be strictly first class.

3. The specifications following are intended to cover only the general features of the instrument. Any modification of

the form proposed herein will be carefully considered, and if deemed of advantage, adopted. When the contract is awarded all matters of detail, design and construction are to be submitted to the representative of the Government for approval, and a copy of the final drawings to be furnished.

4. It is desirable that any estimates submitted be accompanied by preliminary drawings or sketches, approximately to scale, showing the proposed form and principal features of the mounting, accompanied by any description and specification that may be necessary to explain the design.

GENERAL SPECIFICATIONS.

1. The main principle to be borne in mind in designing this telescope is to have an instrument convenient in operation, smooth and satisfactory in running without unnecessary complications.

2. The telescope is primarily intended to be used for spectrographic observations in the Cassegrain form. For this purpose a hole is required in the mirror, the spectrograph being attached below the cell.

3. The telescope in addition must be capable of being used for direct photography at the focus of the principal mirror, both at the side of the tube by the use of a Newtonian flat and directly in the prime focus.

4. A third possible use of the reflector would be with a small and comparatively light spectrograph in the prime focus.

5. Further, it may be desirable to obtain direct photographs at the Cassegrain focus. If the hole in the principal mirror can be made 10 or 12 inches in diameter no additional attachment will be necessary, but if it is not considered desirable to attempt a hole of larger diameter than two or three inches then provision shall be made, in the lower section of the tube, for attaching frame to hold a diagonal mirror to reflect the light to a 10-inch square plate at the side, though such an attachment is not to be furnished at present.

OPTICAL PARTS.

1. The principal and secondary mirrors shall be cast of the material, hard crown, found most suitable and generally used for large mirrors. All the mirrors must be of material free from large visible defects and must be thoroughly and carefully annealed so as to be as free as possible from internal strains.

2. The ratio of thickness to diameter in the principal mirror shall not be less than one to eight and in the smaller mirrors not less than one to six. The principal mirror shall have a central hole cast in it whose diameter is dependent upon conditions. If the diameter can be safely made about one sixth the whole diameter, a third reflection for direct photography in the Cassegrain focus will be avoided. But, if it is considered that a large hole would entail greater danger of non-uniformity of internal structure or would considerably weaken the mirror, then the size of the hole to be cast may be diminished to about two inches which may later be enlarged by grinding to three inches, which is sufficient for spectrographic work.

3. The ratio of aperture to focal length for the parabolic mirror shall be one to five, for the Cassegrain combination one to eighteen. The diameter of the Cassegrain secondary shall be about 19 inches and its radius of curvature about 19·8 feet; while it shall be placed about 7 feet from the principal focus of a 72-inch mirror. For a 60-inch mirror the dimensions will be proportionately reduced. The Newtonian flat for a 72-inch mirror should be elliptical in shape with the apertures of major and minor axes about 20 and 14 inches respectively.

4. All the mirrors shall be ground smooth and true on the periphery, also around the central hole in the main mirror, and shall be ground and polished approximately flat on the back.

5. After the main mirror has been ground approximately to shape it would be desirable for it to stand for some time before figuring, and if possible without delaying the completion of the telescope this should be arranged for.

6. All the optical surfaces shall be of the highest quality both as respects figure and polish. They shall be free from zonal errors and from astigmatism and when tested by the Foucault or knife-edge method shall show perfectly smooth and uniform figures.

7. The main paraboloidal surface is to be tested both at the centre of curvature and at the principal focus. In the former case with the artificial star fixed in position, the centre or focus for zones of different radii shall not vary from the theoretically computed value to a greater extent than $\frac{1}{200}$ inch for the outer zones and $\frac{1}{100}$ for the inner zones. When tested at the principal focus by means of an accurate auxiliary plane, the extreme difference in focus with a fixed artificial star for zones a foot from the edge shall not exceed $\frac{1}{400}$ inch and for the inner zones $\frac{1}{200}$ inch. The same conditions shall be true when the Newtonian is tested in conjunction with the main mirror.

8. The Cassegrain secondary shall be tested in conjunction with the paraboloid and auxiliary plane and the differences of focus allowable, in the images from different zones shall not exceed $\frac{1}{200}$ inch. If found desirable after the instrument is installed, the secondary may be further figured to improve average conditions. The optician shall be ready to do this work without additional charge although his travelling and living expenses will be paid.

9. The diameter of the auxiliary plane used in testing the principal mirror shall be at least three quarters the diameter of the latter and shall be corrected with the highest possible precision. It and the sphere with which it is tested shall be required to be free from zonal errors and from differences of focus for different zones of any measurable or observable amount.

10. The optician shall provide an approved knife-edge apparatus for making these tests. The artificial star shall be formed by condensing the light of a powerful source, the electric arc if necessary, on a small hole not exceeding ·002 inch in diameter. This star shall be capable of adjustment but shall

remain stationary during any tests, the measuring being done by the movement of the knife-edge which shall be effected by micrometer screws working in slides parallel to the optical axis and transversely in any position angle. The whole apparatus to be fixed on a solid stand also possessing all necessary adjustments.

11. Adequate arrangements for maintaining the temperature of the testing room constant, and for the easy and safe handling, adjusting and collimating of the mirrors during testing shall be provided. Provision for the Hartmann test shall be made if required.

12. All the mirrors, including the auxiliary plane, shall fulfil the above requirements and shall be tested by the representative of the Government and any other person or persons who may be asked to act. The maker shall provide all necessary facilities for these tests.

13. Five ordinary and one wide field eye-pieces of suitable foci for visual observations at both the Newtonian and the Cassegrainian focus shall be provided, with the necessary adapters for holding, as well as the necessary guiding eye-pieces for the double slide plate-holder.

14. Two finders of four inches aperture shall be attached in convenient positions at the lower end of the tube. One long focus finder of seven inches aperture and of focal length about that of the main tube shall be attached to the latter and shall be provided with eye-piece with illuminated cross wires. Lateral adjustment of the eye-piece by means of rectangular slides allowing movement of about 15 minutes of arc in any direction with means of clamping when adjusted shall be provided.

MOUNTING

1. The general form of mounting is that having a long polar axis supported on separate columns with the declination axis passing through the polar axis between the bearings. The tube is mounted on one end of this declination axis as close to the polar axis as possible, balance being restored by a system of

counterweights on the far end of the declination bush. Reflectors mounted in a somewhat similar manner are the 4-foot Melbourne, the 4-foot Paris and the 37½-inch Ann Arbor.

2. A spectrograph which may extend as much as eight feet below the mirror cell is to be attached to the lower end of the tube. With the type of mounting described no difficulties are introduced when the tube is on the meridian or above the polar axis. But, as it is frequently convenient to work with the tube under the axis, the length of the polar axis, the form of the columns and other conditions shall be so arranged as to allow this method of working so far as is possible without making the instrument out of proportion or affecting the stability and cost of the mounting. If it is not possible under these conditions to swing eight feet, then the design shall be arranged to allow as long an extension as possible. The diameter of the upper end of the spectrograph will not exceed three feet, while the lower end will be only about half that size.

3. The north and south piers shall be of cast iron provided with means of adjustment in altitude and azimuth, and shall carry the bearings of the polar axis in spherically shaped seats to allow of this adjustment without introducing constraint on axis or bearings. Only so much of these piers as may be considered necessary to provide ample means of adjustment and to allow of proper driving and working of the instrument need be of iron construction and part of the telescope.

4. The polar axis shall be constructed in the best manner of the materials most suitable for the purposes it has to fulfil. If of built-up construction, especial care must be taken to ensure its remaining in alignment when finished. All the bearing surfaces on this axis, as those for the main bearings, for the driving worm wheel, for the main driving gear, for the R. A. circle, or any others must be truly concentric with one another and should if possible, be finished by grinding at one swinging in the lathe. The greatest care must be taken in boring the bearings or bush

for the declination axis to ensure that it is exactly at right angles to the polar axis. If this condition is not fulfilled it is impossible to adjust the telescope for exact following.

5. The declination axis shall be forged in one piece of steel of the best quality for the work it has to do, and all bearing parts as well as those carrying gears or other attachments shall be turned and ground perfectly concentric with one another.

6. The diameters and sections of the polar and declination axes shall be of sufficient size to carry the required weights without undue flexure. The amount of flexure allowable shall be decided by the Government representative.

7. The bearings on both polar and declination axes shall consist of roller bearings entirely. The practice of depending on plain cylindrical bearings for the alignment and of relieving some of the friction by counterpoised rollers, mercury flotation, or other methods is to be abandoned and both alignment and friction taken care of by roller bearings only. Whether bearings like the Timken roller bearing (which provides means of adjustment to take up wear and lost motion) or straight cylindrical roller bearings are to be used, will be decided later. In either case the rollers must be prevented from getting out of place and from sliding against one another by some form of cage or by intermediate smaller rollers. It is essential that the rollers and the external and internal bearing sleeves shall be of steel, hardened and ground with the greatest accuracy.

8. The end thrusts shall also be cared for by means of antifriction bearings, preferably of the roller type and also without sliding friction. Means of adjustment on one of the end thrust bearings on the declination axis will be necessary.

9. Timken roller bearings or some equally good friction-relieving device shall be applied to other bearings in the telescope, where friction will be liable to affect the easy and smooth movement of the telescope. Some that may be mentioned are : — the

bearing of the worm wheel on the polar axis, of the slow motion arm on the declination axis, of the shafts transmitting quick motion in R. A. and Dec. and any others deemed desirable.

10. The principle to be followed in designing the quick and slow motions and the setting circles, is to have the maximum of convenience in operation with the minimum of complication and expense. To this end the following general scheme is suggested though any modifications proposed will be considered.

11. Quick motion in R. A. shall be effected by means of a hand wheel on the south pier, gearing as directly as possible into a large fixed gear on the polar axis. The setting circle in R. A. shall be so arranged that it may be conveniently read from the quick motion wheel, and this circle shall be driven at the sidereal rate so that one may set directly to the R. A. of the star without calculation for hour angle. No fine graduations are required, but the ruling and figures shall be sufficiently distinct to be read directly without magnifier or telescope to minutes of time, and allow of estimation to fifths of a minute. An hour circle coarsely graduated to five minutes of time will also be required.

12. Taking into account accessibility and simplicity, the best method of obtaining the quick motion in declination seems to be by an electric motor mounted on the declination bush and gearing into a large gear keyed to the outer end of the declination axis. The motor shall be actuated from a switch near the R. A. hand wheel, while the declination circle might be near the large gear and read directly from the switch. A moderately coarse graduation easily read without telescope and yet admitting of estimation to 5 minutes of arc and, if feasible by some auxiliary device, even closer is required.

13. The clamp in right ascension should be near the hand wheel and a clutch for disconnecting the latter from the axis if considered necessary. The clamp in declination must be near the quick motion switch, and it is necessary to arrange an interlocking device so that the act of clamping will disconnect the

motor and that the tube must be unclamped before it is possible to start the motor.

14. The foregoing specifications have shown that the intention is to have the preliminary quick setting and clamping of the telescope in R. A. and Dec. made from one position, at or near the south pier as probably the most direct and convenient place.

15. The slow motions in both R. A. and Dec. shall be effected by means of electric motors, these motors being actuated from small switch contacts which may be held in the hand of the observer and of which there shall be two sets, one at the upper and one at the lower end of the tube to enable the final setting and guiding to be done at the finders and guiding eye-pieces.

16. The slow motion in R. A. shall be applied by means of differential gears in the worm shaft or clock train, these gears being driven by a small motor and no arm and tangent screw motion is necessary.

17. The slow motion in declination shall also be actuated by means of an electric motor, the necessary communicating mechanism being sufficiently rigid to ensure that the tube may be started and moved in declination, smoothly and without springiness or lost motion. Friction in the mechanism must be relieved by rollers or balls so that when unclamped the tube may move easily and freely.

18. The speed for the quick motions shall be about 45° to the minute and for the slow motions about 30 minutes of arc to the minute, and the motors must be provided with some kind of brake or clutch so that the telescope stops when the switch is opened.

19. The tube above its attachment to the declination axis shall be of skeleton construction, below, of closed construction. The lower part shall be of cast iron, or steel and cast iron, or of other materials as may best answer the purpose. Such openings in the sides of the lower section near the mirror, closed by

light removable covers, as may be deemed necessary for convenience in burnishing the mirror or for other purposes, shall be made.

20. The mirror cell shall be of cast iron of substantial construction, rigidly attached and yet easily removable for the purpose of re-silvering. The mirror shall be supported on the back in the cell by a system of counterweighted levers or by any other suitable system, such as a multiple three-point support, which will equally distribute the weight of the mirror. An edge support system like that used on the 60-inch Mount Wilson telescope shall be used to maintain collimation without undue stress on the edge of the mirror.

21. As the latest experience has shown that nothing is gained, so far as temperature effects on the mirror are concerned, by leaving the cell open at the back it may preferably be entirely closed in, except a central aperture as large as the hole on the mirror.

22. An attaching ring about 3 ft. in diameter shall be cast on and turned up true on the bottom of the cell with convenient appliances for attaching and orienting the spectrograph and other accessories.

23. Some convenient and effective means of covering the mirror, which shall at the same time act to a certain extent as a heat insulator, shall be provided.

24. For the skeleton section of the tube above the declination axis, the construction shall be as light as is consistent with maintaining the mirrors in good collimation. As a first approximation the amount of flexure allowable at the Cassegrain mirror situated about 19 ft. above the surface of a 60-inch and nearly 23 ft. above a 72-inch mirror shall not exceed one-eighth of an inch when the tube is horizontal. The flexure when the instrument is used in the prime focus with the heavier extensions required, need not be so small and a tube to carry the Cassegrain with the above flexure would be sufficiently rigid for all purposes.

25. The upper end of the tube shall be so designed as to allow the necessary changes from one form of the telescope to another (Cassegrain, Newtonian and prime focus) to be made with the minimum of risk, labor, and change of balance.

26. The Cassegrain mirror, which for a 72-inch telescope is of about 19 inches aperture and situated nearly 23 feet from the surface of the principal mirror, must be held firmly and yet without constraint in its cell, and cell and mirror shall be capable of being easily and accurately adjusted for collimation. After collimation has been effected the system must be movable with a slow smooth motion along the optical axis for the purpose of focussing. This motion must be carried by rods and gearing to the lower end of the tube near the guiding eye-piece of the spectrograph and must not change the collimation. The mirror and system is to be held in position by four arms of thin steel plate, placed edgewise, attached firmly to the periphery of the tube.

27. When the telescope is used in the Newtonian form or at the prime focus the Cassegrain must be removed to prevent obstruction of the light and when used at the prime focus the Newtonian mirror must be removed for the same reason. One double-slide plate-holder, attachable either at the Newtonian or prime focus, with the necessary focussing and adjusting devices and guiding eye-pieces, shall be provided. When used at the prime focus, provision must be made for carrying the plate-holder movements and guiding eye-piece to the side of the tube. The plate used in this plate-holder will be 4 inches square, and care must be taken in the design that light from the whole mirror, except that occulted at the centre, shall reach every part of this plate unobstructed. The Newtonian attachment and also that in the prime focus shall be provided with convenient means of rotation and clamping in position angle to bring the plate-holder or other attachments to a convenient position for guiding. The adapters or attachments in which the plate-holder is held must be designed to admit of the use of a small spectrograph.

28. The tube must be attached to the declination axis at such a place that, with the Cassegrain in place and no spectrograph below the mirror, the tube is nearly in balance. Balance will be restored when the spectrograph is attached by weights placed north and south of the upper end of the tube. Provision for attaching weights below the cell for restoring balance when the other attachments are in use must be made.

29. The driving clock shall be of ample size to do the work and made in the best manner. Great care must be taken with the communicating gears and shafts between the governor and the worm shaft to prevent the introduction of any periodic error in driving. The clock shall be wound automatically by an electric motor.

30. The connection between clock and worm shaft shall be as direct as possible and if differential gears are introduced in the worm shaft, care must be taken that the two parts of the shaft are exactly concentric else a period may be introduced. Provision must be made in the connection to allow the adjustment of the telescope in altitude and azimuth without affecting the driving.

31. The driving worm itself which is often at fault must be most carefully made. It must be turned and the worm cut as truly as possible and finished by grinding. The screw part should be left considerably longer than will be used and ground and lapped in a long nut to remove all chance of periodic error.

32. The driving worm wheel shall be as large as possible in diameter. If the design of the polar axis is properly carried out, the worm wheel might, when the telescope is turned to the pole, the only place where interference can occur, project up behind the mirror cell for at least a foot as the spectrograph or any other attachment below the cell will not be greater than 3 ft. in diameter. The worm wheel is to be spaced and cut with the greatest possible accuracy. The teeth shall be smoothed up and any remaining irregularities removed by running worm and wheel together with polishing material, care being taken that all

grinding material is removed from worm and wheel. The whole driving mechanism must be carefully made as periodic error in driving is a most annoying and troublesome defect.

33. A complete and permanent system of wiring for illuminating the circles and guiding eye-pieces and for the quick and slow motion motors with 12 additional wires for the spectrograph shall be provided on the telescope, but bearing rings and brushes to be avoided if possible.

34. For transport conditions it is desirable and almost essential that no single piece of the telescope weigh more than five tons.

35. The price given shall include the cost of boxing and delivering F.O.B. at the place of manufacture and the services of a competent person to superintend the erection of the instrument, which shall not be considered completed until it operates to the satisfaction of the representative of the Government.

36. Terms of payment desired should be stated in the tender.

LOCATION OF EPICENTRES FOR 1912

By Otto Klotz

THE following is in continuation of a similar series published last year for 1911. The method followed has been identical with the former of plotting on our printed forms for each station, which has the necessary data, the arc upon which the epicentre lies, by means of our published stereographic projection tables. The intersection of three or more arcs at or near a common point gives then the co-ordinates of the epicentre required. In the accompanying table, column 1, gives the dates of the quakes whose locations were attempted with the data at hand. When two quakes fall upon the same day they have been differentiated by giving the nearest hour (G.M.T.) of the beginning of the disturbance. Columns 2 and 5 give all the data available, the distance being in kilometres, and taken directly, when given, from the various bulletins, or deduced from the *P* and *S* times. Column 2, however, gives only those station for which the intersections are satisfactory, and of such intersections the centre of gravity is taken for the epicentre, the co-ordinates of which are then found in column 3. The remaining data, unsatisfactory or conflicting with that of column 2 are entered in column 5 as "other data." When all the data give unsatisfactory intersections then in column 2 is put "no location," and the stations used appear as "data" in column 5. Last year we gave in column 4, the values for the geographical co-ordinates determined by Prince Galitzin from his own instrument alone, that is, from the record of one station, and those of Professor Zeissig, who computes the position from the difference of times of arrival of the wavefront of the first or *P* waves at his and another station. In the bulletins and reports received we find the position of the epicentre given by other stations also, and these have been

entered too in column 4. Whenever the position of an earthquake has been learned through the Press, it is indicated in column 5 by giving the place.

To come back to the intersections. As was pointed out on former occasions, the failure to intersect exactly and often far from exactly, is due to erroneous distances resulting from various causes :—

1. Readings of the seismogram. These are the readings of P and S. Errors of the former are probably less often made than of the latter, as far as the actual seismogram is concerned.

2. Errors arising from a false interpretation of the diagram ; for instance, that which is read as P may be PR_1, as may happen for distant quakes, where the horizontal component of P is less than for PR_1, and hence the former may not record at all, so that the time interval read is too small and the distance deduced therefrom too small also. Such error may be attributed to lack of sensitiveness of the instrument.

3. Errors arising from clock errors are practically eliminated in methods like ours, where the difference of times, $S - P$, is used for obtaining the distance. However, for other purposes the clock error should be confined within a second, which has not been the case at many stations. However, there is a marked improvement now, and this will increase by the ever greater use made of the time signals sent out by the various national wireless stations.

4. Then too there is an inherent error at times with reference to two stations. The earthquake never emanates from a geometrical point, as we deal with it in its location, but from a surface or volume, of greater or less extent, so that different azimuths come into play for the various stations, and hence different times for P and S, than if the quake issued from a point.

5. And finally our velocity tables are yet imperfect, but I may add, do not affect distances deduced as much as some of the preceding causes. The tables issued from Göttingen, deduced

as they are, will not suffer material change hereafter, for distances up to say 10,000 kms.

However, we must draw attention to the effect of impulses issuing from different depths, as pointed out by the writer for the Calabrian quake in a short paper in the JOURNAL of the Royal Astronomical Society of Canada, No. 1, 1909. We may take it for granted that, speaking generally, a quake at a greater depth has more energy than one at a less depth, for the resistance to be overcome in the former case is greater than in the latter. Hence we may expect to find the former earthquakes to be propagated a greater distance than the latter. This difference of depth must necessarily carry with it a difference of velocity curve, as the two impulses start in different media. Again, in the debâcle, which we can scarcely believe to be instantaneous, we may have a record at a comparatively near station, being from a hypocentre of small depth, which possibly fires the tectonic quake, giving their records at distant stations. The records from these hypocentres with the same epicentre are, therefore, not strictly comparable, and by present methods create discrepancies in our results. From such considerations then, a uniform table or single velocity curve does not eliminate discordances found. However for the preliminary determination of distance that is made by many stations immediately or soon after a tectonic quake, we will be obliged, from force of circumstances, to adhere to a single velocity curve. Only later, upon a thorough discussion of the quake, can differential tables be applied. Recently Professor Dr. Ludwig Pilgrim has published a paper on this question in *Gerland's Beiträge*, XII. Band, 3 Heft.

It appears to the writer that the International Seismological Association is the proper medium to undertake the construction of new velocity curves or velocity tables. The Wiechert-Zöppritz curves were constructed in 1906 and were based essentially on three tectonic quakes: the Indian of April 4, 1905; the Calabrian of September 9, 1905; and the Californian of April 18, 1906. Since then there have been quite a number of severe quakes on land, whose geographical co-ordinates are consequently

known, and, besides, the instrumental outfits have been greatly improved, as well as the reliability of the time at the earthquake stations. The number of observing stations has also materially increased, so that the compilation and digestion of the available data would give us velocity tables approaching an accuracy that would practically eliminate errors and uncertainties that still exist due to that cause, besides furnishing data for geophysicists in the study of the varying elasticity and varying density of the earth, together with their anomalies. The bureau of the International Association should be the clearing house for all earthquake stations. There, all earthquake data should be gathered, including copies of seismograms of tectonic quakes, put into the scientific mill and ground, but remembering with Huxley, that we cannot extract wheat-flour from peas-cods.

For location purposes it has hitherto been a disappointment that data from far eastern stations were not available, particularly from Japan, which publishes otherwise so much valuable seismological matter. However, now by the splendid service inaugurated by Russia, with stations throughout Siberia, to the Pacific, and Zi-ka-wei also, we can locate a tectonic quake with good records pretty effectively, but there is room for improvement. Our method of location of earthquakes is a species of triangulation, and it is obvious that stations widely distributed are better adapted therefor, than those close to each other, as they are in central Europe. In the northern hemisphere modern instruments might be installed with advantage to seismology at Prince Rupert, Dawson, Unalashka, Midway, Guam, Bangkok, Trinidad, Panama, to name only some of the desirable places. The difficulty of out-of-the-way stations is not the cost of installation, which in most cases would be readily met, but in the intelligent and satisfactory attendance of the instruments by persons who have quite other duties to perform. Seismology has enough difficulties and difficult problems of its own without burdening it with unreliable and unsatisfactory data.

The stereographic plotting has been done by R. C. McCully of our office.

Location of Epicentres for 1912

Note.— The figures following a station in the 2nd and 5th columns refer to the distance in kilometres from the respective station to the epicentre.

G's and Z's stand for Galitzin's and Zeissig's values respectively.

Date	Stations	Epicentre		Remarks
Jan. 4	Aachen = 8700 Hamburg = 8300 Manila = 6600 Ottawa = (?) 7000 Pulkowa = 7450	$\varphi = 50^{\circ}\ 40'$ $\lambda = 179^{\circ}54'$E.	G's $\varphi = 49^{\circ}\frac{1}{2}$ $\lambda = 175^{\circ}$E. Z's $\varphi = 50^{\circ}\frac{1}{2}$ $\lambda = 176^{\circ}$W.	Other data : Cartuja = 10350, Göttingen = 8500, Tiflis = 8650, Vienna = 8650, Zi-ka-wei = 5350. The above give intersections in the vicinity of the adjoining epicentre.
Jan. 31 (13h).	No Location Arcs nearly tangent to each other.			Data : Cartuja 7800, Göttingen 6600, Graz 6400, Vienna 5900,
Jan. 31 (20h).	Cartuja = 8700 Göttingen = 7400 Hamburg = 7200 Ottawa = 4800 Pulkowa = 6600 St. Louis = 4550 Strassburg = 7750 Zi-ka wei 7150	$\varphi = 60^{\circ}\ 00'$ $\lambda = 146'36'$W.		Vienna = 7750 comes fairly close. Heavy earthquake shocks felt throughout southwestern Alaska. Other data : Spring Hill = 5900, St. Boniface = 3350.
Mar. 11	No Location			Data : Cleveland = 1800, Harvard (?) 1800, Laibach 11950, Ottawa = 3050, Pulkowa = 7550, St. Boniface = 2250. Vienna = 9250.
Apr. 17	No Location			Data : Hamburg = 8850, Harvard = 4850, Göttingen = 9000, Ottawa = 4150, Pulkowa = 5700, Vienna = 10000.
Apr. 20	No Location		G's $\varphi = 27^{\circ}\ 30'$ $\lambda = 135^{\circ}30'$E.	Data : Aachen = 8700, Graz = 8150,

LOCATION OF EPICENTRES FOR 1912

Date	Stations	Epicentre		Remarks
				Irkutsk = 8575, Pulkowa = 8200, Vienna = 10100, Zi-ka-wei = 4750, Göttingen = 2400, Harvard = 3850.
May 6	Aachen = 2200 Cartuja = 3250 Graz = 2950 Hamburg = 2150 Irkutsk = 6300 Laibach = 2950 Ottawa = 3900 Pulkowa = 2600 Vienna = 2850	$\varphi = 64^\circ\ 32'$ $\lambda = 21^\circ 45'$ W.	$\varphi = 63^\circ{\cdot}8$ $\lambda = 20^\circ\ 00'$ W. Z's $\varphi = 64^\circ\ 30'$ $\lambda = 21^\circ\ 30'$ W. Aachen $\varphi = 64^\circ$ $\lambda = 22^\circ$ W. Cartuja $\varphi = 63^\circ$ $\lambda = 23^\circ\frac{1}{2}$ W. Graz $\varphi = 63^\circ{\cdot}5$ $\lambda = 23^\circ{\cdot}0$ W.	Jugenheim = 2500, Strassburg = 2550, Zi-ka-wei = 9000 agree fairly well with adjoining. Other Data: Cleveland = 3000, Spring Hill = 5150, St. Boniface = 4700, Tiflis = 4550.
May 23	(i) Athens = 7300 Hamburg = 8000 ca. Irkutsk = 3400 Pola = 8000 Pulkowa = 6750	$\varphi = 21^\circ\ 48'$ $\lambda = 99^\circ\ 10'$ E.	G's $\varphi = 20^\circ{\cdot}3$ $\lambda = 96^\circ{\cdot}3$ E. Z's(Ham.-Pots.) $\varphi = 4^\circ{\cdot}5$ $\lambda = 73^\circ$ E.	Other data: Aachen = 8250, Cartuja = 9250, Graz = 7700, Jugenheim = 7850, Laibach = 8150, Makejevka = 5750, Manila = 5300, Ottawa (?) = 8300, Strassburg = 8300, Tiflis = 5500.
May 23	(ii) Göttingen = 7900 Irkutsk = 3400 Zi-ka-wei = 2600	$\varphi = 22^\circ\ 02'$ $\lambda = 97^\circ\ 03'$ E.	Z's (Alg.Rocca&P.) $\varphi = 23^\circ$ $\lambda = 95^\circ\frac{1}{2}$ E. Cartuja $\varphi = 22^\circ$ $\lambda = 96^\circ$ E. Graz $\varphi = 4^\circ{\cdot}5$ $\lambda = 73^\circ$ E. Irkutsk $\varphi = 22^\circ{\cdot}5$ $\lambda = 99^\circ$ E.	Vienna = 7600.

Location of Epicentres for 1912

Date	Stations	Epicentre		Remarks
June 7 (10h).	(i) Harvard = 5600 Irkutsk = 5900 Ottawa = 5200 Pulkowa = 6800	$\varphi = 58^\circ 24'$ $\lambda = 152^\circ 45'$W.		Violent eruption at Katmai, Alaska. Other data : Strassburg = 6500, Vienna = 9300.
	(ii) Cartuja = 9200 Pulkowa = 6800 Zi-ka-wei = 6450	$\varphi = 58^\circ 10'$ $\lambda = 161^\circ 15'$W.		
June 7 (12h).	Ottawa = 5500 Pulkowa = 6950 Zi-ka-wei = 6600	$\varphi = 57^\circ 40'$ $\lambda = 157^\circ 40'$W.		
June 7 (18h).	(i) Strassburg = 7800 Tiflis = 8750 Vienna = 7850 Zi-ka-wei = 7450	$\varphi = 58^\circ 42'$ $\lambda = 142^\circ 40'$W.	Cartuja $\varphi = 57^\circ \cdot 4$ $\lambda = 160^\circ$ W.	
	(ii) Cartuja = 9300 Irkutsk = 5750 Tiflis = 8750	$\varphi = 56^\circ 56'$ $\lambda = 159^\circ 00'$W.	Irkutsk $\varphi = 59^\circ 37'$ $\lambda = 153^\circ 27'$W.	
June 8 (7h).	Cartuja = 9050 Harvard = 5800 Ottawa = 5250 Pulkowa = 6900	$\varphi = 57^\circ 56'$ $\lambda = 154^\circ 00$W.		Other data : Apia = 8100, Göttingen = 5550, Irkutsk = 4750, Pola = 1800.
June 8 (13h).	Irkutsk = 5900 Pulkowa = 6900 Strassburg = 8000	$\varphi = 57^\circ 58'$ $\lambda = 152^\circ 03'$W.	G's $\varphi = 57^\circ \cdot 7$ $\lambda = 166^\circ \cdot 1$ W.	Graz = 8350, comes fairly close. Other data : Hamburg = 7250, Laibach = 9100, Vienna = 8950.
June 9	Irkutsk = 5850 Ottawa = 5450 Pulkowa = 7000	$\varphi = 56^\circ 48'$ $\lambda = 156^\circ 33'$W.	G's $\varphi = 57^\circ \cdot 5$ $\lambda = 149^\circ \cdot 7$ W. Irkutsk $\varphi = 58^\circ 46'$ $\lambda = 153^\circ 48'$W.	Strassburg = 9000, does not agree.
June 10	Aachen = 7900 Harvard = 5900 Irkutsk = 5850 Ottawa = 5300 Pulkowa = 7000	$\varphi = 57^\circ 02'$ $\lambda = 154^\circ 30'$W.	$\varphi = 56^\circ \cdot 9$ $\lambda = 158^\circ \cdot 1$ W.	Other data : Cartuja = (?) 9300, Göttingen = 8600, Laibach = 9250, Makejevka = 8000, Pola = 9000, Strassburg = 8400, Vienna = 8350.

LOCATION OF EPICENTRES FOR 1912

Date	Stations	Epicentre		Remarks
June 12 (7h).	No Location		G's $\varphi = 57°{\cdot}7$ $\lambda = 149°{\cdot}3$ W.	Data : Irkutsk = 5800, Pulkowa = 6950, Tiflis = 8400.
June 12 (12h).	(i) Aachen = 9100 Hamburg = 9100 Ottawa = 3600 Pulkowa = 9350	$\varphi = 31° 24'$ $\lambda = 113° 36'$ W.	G's $\varphi = 25°{\cdot}0$ $\lambda = 94°{\cdot}9$ W.	Other data : Graz = 9200, Harvard = 3500, Laibach = 9750, Strassburg = 9600, Vienna = 9250.
	(ii) Cartuja = 8500 Irkutsk = 11200 Pulkowa = 9350	$\varphi = 25° 06'$ $\lambda = 95° 30'$ W.	Cartuja $\varphi = 26°{\cdot}4$ $\lambda = 96°$ W.	
June 17	No Location		G's $\varphi = 57°$ $\lambda = 149°{\cdot}7$ W.	Data : Irkutsk = 4850, Makejevka = 8050, Pulkowa = 7150, Vienna = 7600.
June 18	No Location		G's $\varphi = 39°{\cdot}9$ S. $\lambda = 16°{\cdot}5$ W.	Data : Cartuja = 11650, Ottawa = 4300, Pulkowa = 11750 Tiflis = 10300, Vienna = 8850.
June 29	No Location			Harvard = 8000, Makejevka = 8800, Ottawa = 7750, Pulkowa = 8700, Vienna = (?) 4800.
July 7 (8h).	(i) Athens = 8800 Cartuja = 8600 Harvard = 5350 Jugenheim = 7500 Ottawa = 4850 Spring Hill = 5450	$\varphi = 61° 10'$ $\lambda = 148° 04'$ W.	G's $\varphi = 63°{\cdot}3$ $\lambda = 157°{\cdot}4$ W.	Quake reported at Fairbanks, Alaska. Vienna = 7800 comes fairly close.
	(ii) Aachen = 7200 Cartuja = 8600 Hamburg = 7000 Makejevka = 7700 Pulkowa = 6300 Strassburg = 7500 Tiflis = 8200	$\varphi = 63°$ $\lambda = 154° 24'$ W.	Z's $\varphi = 61°$ $\lambda = 150°$ W.	Zi-ka-wei = 6700 comes fairly close.

Location of Epicentres for 1912

Date	Stations	Epicentre		Remarks
July 7 (8h).	(iii) Cartuja = 8600 Graz = 7800 Irkutsk = 5700 Jugenheim = 7500 Makejevka = 7700	$\varphi = 62^{\circ}02'$ $\lambda = 151^{\circ}30'$ W.	Cartuja $\varphi = 62^{\circ}$ $\lambda = 157^{\circ}\cdot3$ W.	
	(iv) Aachen = 7200 Hamburg = 7000 Harvard = 5350 Ottawa = 4850 Makejevka = 7700 Spring Hill = 5450 Strassburg = 7500	$\varphi = 62^{\circ}22'$ $\lambda = 148^{\circ}36'$ W.	Irkutsk $\varphi = 65^{\circ}$ $\lambda = 159^{\circ}\cdot5$ W. Makejevka $\varphi = 62^{\circ}$ $\lambda = 153^{\circ}\cdot9$ W.	All of these four (i, ii, iii, iv) intersections are good.
July 7 (23h)	Aachen = 9400 Cartuja = 8650 Pulkowa = 10650	$\varphi = 6^{\circ}20'$ $\lambda = 83^{\circ}20'$ W.	Cartuja $\varphi = 2^{\circ}\cdot6$ N. $\lambda = 74^{\circ}\cdot5$ W.	Other data: Graz = 9400, Hamburg = 9100, Harvard = 11250, Strassburg = 9000.
July 8	(i) Cartuja = 8650 Graz = 7800 Ottawa = 4900 Zi-ka-wei = 6950	$\varphi = 61^{\circ}30'$ $\lambda = 149^{\circ}36'$ W.	G's $\varphi = 63^{\circ}\cdot1$ $\lambda = 154^{\circ}\cdot9$ W.	Other data: Hamburg = 6800, Harvard = 5600, Vienna = 7900. These stations differ somewhat with adjoining.
	(ii) Cartuja = 8650 Gottingen = 7200 Graz = 7800 Makejevka = 7600 Pulkowa = 6350 Spring Hill = 5900	$\varphi = 62^{\circ}48'$ $\lambda = 157^{\circ}24'$ W.	Makejevka $\varphi = 63^{\circ}\cdot1$ $\lambda = 149^{\circ}\cdot4$ W.	
	(iii) Aachen = 6950 Irkutsk = 5900 Makejevka = 7600 Tiflis = 8300	$\varphi = 63^{\circ}40'$ $\lambda = 141^{\circ}30'$ W.		
July 9	(i) Irkutsk = 8450 Pulkowa = 6400 Vienna = 5400	$\varphi = 2^{\circ}12'$ $\lambda = 34^{\circ}24'$ E.	G's $\varphi = 2^{\circ}\cdot1$ $\lambda = 30^{\circ}\cdot3$ E.	Strassburg = 5800 falls fairly close. Other data: Makejevka = 4850, Tiflis = 3650.
	(ii) Cartuja = 5250 Graz = 5150 Irkutsk = 8450	$\varphi = 3^{\circ}14'$ $\lambda = 32^{\circ}42'$ E.		Gottingen ca. = 5700 falls fairly close.

Location of Epicentres for 1912

Date	Stations	Epicentre		Remarks
July 24	No Location Intersections scattered		G's $\varphi = 10°{\cdot}7$ S. $\lambda = 88°{\cdot}2$ W.	Quake reported from Piura, Peru. Data : Aachen (?) = 8900, Cartuja = 9000, Graz = 9300, Hamburg = 9300, Harvard = 5150, Irkutsk = 4650, Ottawa = 5300, Pola = 6000, Pulkowa = 12600, Strassburg = 9250, Tiflis = 6200, Vienna = 9000, Zi-ka-wei = 3150.
July 25	Irkutsk = 7800 Pulkowa = 9600 Strassburg = 10750	$\varphi = 32°\,54'$ $\lambda = 154°\,42'$ W.		Other data : Cartuja = 13150, Lemberg ca. = 12000, Manila = 2650, Tiflis = 2850, Vienna = 11200, Zi-ka-wei = 5400.
Aug. 6	Irkutsk = 8950 Ottawa = 3500 Tiflis = 10750	$\varphi = 40°\,08'$ $\lambda = 118°{\cdot}24'$ W.	G's $\varphi = 13°{\cdot}2$ $\lambda = 152°{\cdot}8$ E.	Other data : Manila = 2500, Pulkowa = 10450, Zi-ka-wei = 6650.
Aug. 9	(i) Aachen = 1950 Göttingen = 1900 Vienna = 1400	$\varphi = 35°\,46'$ $\lambda = 19°$ E.	G's (i) $\varphi = 41°$ $\lambda = 26°{\cdot}6$ E. (ii) $\varphi = 39°{\cdot}5$ $\lambda = 20°{\cdot}2$ E.	Reported near Gallipoli.
	(ii) Cartuja = 2800 Irkutsk = 5850 Tiflis = 1450	$\varphi = 38°\,20'$ $\lambda = 28°\,27'$ E.	Irkutsk $\varphi = 41°{\cdot}5$ $\lambda = 27°{\cdot}5$ E.	Spring Hill = 9850, Vienna = 1400, Zi-ka-wei = 8200, come fairly close.
	(iii) Göttingen = 1900 Harvard = 7750 Irkutsk = 5850 Ottawa = 7800 Pulkowa = (2) 2250 Strassburg = 1800 Zi-ka-wei = 8200	$\varphi = 30°\,40'$ $\lambda = 27°$ E.	Strassburg $\varphi = 40°\,40'$ $\lambda = 27°\,24'$ E. Tiflis $\varphi = 41°{\cdot}8$ $\lambda = 27°{\cdot}8$ E.	Aachen = 1950 comes fairly close. Number (iii) seems to be the point having the greatest support.

Location of Epicentres for 1912

Date	Stations	Epicentre		Remarks
Aug. 17	Aachen = 9650 Ottawa = 9000 Tiflis = 8900	φ = 39° 22′ λ = 160° 33′ E.	G's φ = 98°·9 λ = 124° E. Irkutsk φ = 3°·0 λ = 117° E. Tiflis φ = 98°·5 λ = 123°·3 E	Laibach = 10000, Vienna = 9700, come fairly close. Other data : Athens = 10050, Göttingen = 9500, Graz = 9650, Hamburg = 9400, Irkutsk = 5700, Manila = 2650 Pulkowa = 9450, Zi-ka-wei = 2950.
Aug. 18	No Location			Data : Graz 9550, Harvard (?) = 2650, Irkutsk = 3400, Ottawa = 3200, Pulkowa = 7950. Reported from Williams, Arizona.
Aug. 31	(i) Pulkowa = 6900 Tiflis = 7900 Zi-ka-wei = 3600	φ = 49° 54′ λ = 157°·00′ E.	G's φ = 49°·9 λ = 156°·7 E.	Other data : Graz = 9000, Strassburg = 8800,
	(ii) Hamburg = 8350 Irkutsk = 3800 Zi-ka-wei = 3606	φ = 47° 34′ λ = 158°·06 E.		
Sept. 1	No Location Ares very scattered.			Data : Manila = 1850, Ottawa = 4300, Pulkowa = 13500, Strassburg = 6600, Vienna = 4700, Zi-ka-wei = 4700.
Sept. 13	(i) Aachen = 1970 Cartuja = 2650 Hamburg = 1900 Irkutsk = 5800 Pulkowa (2) = 2220	φ = 40° 22′ λ = 26° 24′ E.	G's (i) φ = 41°·1 λ = 26°·4 E. (ii) φ = 40°·1 λ = 26°·3 E.	Other data : Laibach = 1650, Ottawa (?) = 4000, Pulkowa (1) = 2090.
	(ii) Graz = 1330 Irkutsk = 5800 Pulkowa (2) = 2220 Strassburg = 1900 Tiflis = 1420	φ = 39° 52′ λ = 27° 57′ E.	Irkutsk φ = 39°·3 λ = 28°·1 E. Tiflis φ = 42° λ = 27°·4 E.	

Location of Epicentres for 1912

Date	Stations	Epicentre		Remarks
Sept. 29	Irkutsk = 5550 Pola = 11000 Tiflis = 8550	$\varphi = 4^\circ 32'$ $\lambda = 121^\circ 26'$ E.	G's $\varphi = 16^\circ{\cdot}6$ $\lambda = 138^\circ{\cdot}6$ E.	Other data: Graz = 9400, Laibach = 10500, Ottawa (?) = 9600, Pulkowa = 9400, Vienna = 11000, Zi-ka-wei = 3050
Oct. 12	Irkutsk = 4950 Pulkowa = 7450 Tiflis = 8800 Vienna = 8900	$\varphi = 50^\circ 24'$ $\lambda = 178^\circ 45'$ E.	G's $\varphi = 50^\circ{\cdot}9$ $\lambda = 177^\circ{\cdot}1$ W.	Zi-ka-wei = 5250 comes fairly close. Aachen = 8900, Graz = 9400, Ottawa = 5450.
Oct. 18	Aachen = 8600 Hamburg = 8200 Manila = 4650 Pulkowa = 7000	$\varphi = 47^\circ 30'$ $\lambda = 152^\circ 57'$ E.	G's $\varphi = 54^\circ{\cdot}6$ $\lambda = 179^\circ{\cdot}2$ E.	Other data: Graz = 8900. Harvard = 5850, Ottawa = 5650, Vienna = 8700.
Oct. 31 (12h).	No Location		G's $\varphi = 36^\circ$ $\lambda = 35^\circ$ W.	Data: Aachen = 2600, Graz = 5300, Pulkowa = 5250, Vienna = 4400.
Oct. 31 (18h).	No Location Intersections very scattered.		G's $\varphi = 11^\circ{\cdot}2$ $\lambda = 128^\circ{\cdot}8$ E.	Data: Aachen = 8000, Graz = 9500, Irkutsk = 5650, Makejevka = 9350, Pulkowa = 9400, Tiflis = 9250, Zi-ka-wei = 2750.
Nov. 7 (8h).	(i) Aachen = 7900 Cartuja = 9250 Graz = 8400 Irkutsk = 5850 Pulkowa = 7000 Strassburg = 8250 Vienna = 8300	$\varphi = 56^\circ 42'$ $\lambda = 156^\circ 20'$ W.	G's $\varphi = 56^\circ{\cdot}5$ $\lambda = 166^\circ{\cdot}3$ W.	Hamburg = 7600, comes fairly close. Quake reported at Seward, Alaska.
	(ii) Harvard = 5700 Irkutsk = 5850 Makejevka = 8150 Zi-ka-wei = 6800	$\varphi = 58^\circ 12'$ $\lambda = 153^\circ 33'$ W.	Cartuja $\varphi = 57^\circ{\cdot}4$ $\lambda = 162^\circ$ W.	
	(iii) Aachen = 7900 Graz = 8400 Hamburg = 7600 Ottawa = 5100 Tiflis = 8950 Vienna = 8300	$\varphi = 56^\circ 18'$ $\lambda = 150^\circ 33'$ W.	Irkutsk $\varphi = 69^\circ{\cdot}2$ $\lambda = 147^\circ{\cdot}9$ W.	Pulkowa = 7000, comes fairly close.

Location of Epicentres for 1912

Date	Stations	Epicentre		Remarks
Nov. 7 (17h).	Graz = 9000 Irkutsk = 8250 Ottawa = 3750	φ = 45° 08′ λ = 124°·03 W.		
Nov. 19	No Location Arcs nearly tangent			Quake reported from Acambay, Mexico. Data : Aachen = 9500, Harvard = 4200, Ottawa = 3500, Pulkowa = 9600, Spring Hill = 2200, Vienna = 10300.
Dec. 5	Aachen = 7800 Hamburg = 7550 Irkutsk = 5900 Ottawa = 5300 Pulkowa = 7000 Strassburg = 8200 Tiflis = 8900 Zi-ka-wei = 6800	φ = 57° 08′ λ = 154°·15′ W.	G's φ = 57°·0 λ = 134° W. Cartuja φ = 54°·6 λ = 135°·5 W. Irkutsk φ = 56°·4 λ = 155°·4 W.	Other data : Graz = 8200, Cartuja = 9000, Harvard = 3850, Vienna = 7700.
Dec. 7	Cartuja = 2050 Harvard = 7100 Ottawa = 7300 Vienna = 3600	φ = 18° 52′ λ = 0° 51′ W.		Other data : Aachen = 4000, Graz = 8450, Hamburg = 4950, Irkutsk = 8650, Pulkowa = 14000, Zi-ka-wei = 3500.
Dec. 9	Cartuja = 8000 Ottawa = 3600 Vienna = 9400	φ = 13° 28′ λ = 81°·15′ W.	G's φ = 19° λ = 85° W.	Other data : Aachen = 9400, Graz = 10400, Hamburg (?) = 9250, Pulkowa = 9500.
Dec. 24	No Location Intersections very scattered.		G's φ = 5°·3 λ = 117° E. Irkutsk φ = 53°·5 λ = 157°·7 W.	Data : Aachen (?) = 4200, Graz = 4950, Irkutsk = 6100, Ottawa (?) = 5000, Pulkowa = 9300, Tiflis = 8500, Vienna = 9450.

Dominion Observatory,
Ottawa, Canada,
March 31, 1913.

THE ORBIT OF 88 *d* TAURI

By W. E. Harper

THIS star, whose right ascension is four hours thirty minutes, declination north nine degrees fifty-seven minutes, photographic magnitude 4·5, was announced as a spectroscopic binary by Moore in *L. O. B.* 4, 162, 1907. A second announcement as to its binary nature was made last year from the Mt. Wilson Observatory. Possibly as it was given in their list by the number 88 they had overlooked the previous announcement of the same star under the designation *d* Tauri by the Lick astronomers.

The early observations of Moore, five in all, have been of great value in determining the period. Between the first observation at Lick and the last one here an interval of about 750 periods has elapsed, so that it is possible to arrive at a value for the period which must be very near the true value. The period 3·5711 days was considered the best until the observations were grouped and a solution made, when it was seen that by increasing the period to 3·5712 days (an increase of about nine seconds) a better agreement with the curve would be secured. This latter value, then, was the period adopted.

The star is of the hydrogen type, being designated A_2 in the Harvard classification, though it approaches somewhat closer than that to the *F*-type as, with proper exposure, a number of metallic lines in the spectrum can be seen. The single prism camera was used throughout and of the 28 plates secured 8 were made on Seed 30 emulsion, 4 on Seed 23 and 16 on the regular Seed 27. The lines of the spectrum should be fairly well measurable if the plates secured were of good quality, but the continued poor observing weather of the past nine months or so has rendered acceptable almost any kind of plate. As a result

the velocities obtained have a larger probable error than otherwise would be the case, but the fairly high range in velocity compensates for this to a great extent and permits of a fairly accurate determination of the orbital elements. Some lines due to the spectrum of the second component are faintly visible, the finer grained Seed 23 plates being more suitable to record these. Further mention will be made of this later.

The measures at Ottawa as well as those at other observatories are given in the following tables.

MEASURES OF *d* TAURI AT OTHER OBSERVATORIES

Observatory	Date	Julian Date	Phase	Velocity	O--C
Lick	1905 Nov. 18	2417168·888	·717	+ 51·7	+ 3·1
Lick	1906 Oct. 1	7485·966	3·529	+ 103·9	− 0·5
Lick	1907 Aug. 25	7813·993	3·006	+ 65·8	+ 0·3
Lick	1907 Oct. 6	7855·952	2·111	− 34·3	− 6·1
Lick	1907 Oct. 13	7862·895	1·911	− 44·4	− 8·2
Mt. Wilson	1911 Oct. 9	9319·909	1·876	− 43	− 6
Mt. Wilson	1911 Nov. 3	9344·039	1·907	− 40	− 3
Mt. Wilson	1912 Jan. 5	9407·829	·516	+ 71	− 2

OTTAWA MEASURES OF *d* TAURI

Plate No.	Kind of Plate	Date	Julian Day	Phase	Velocity	Weight	Residual O−C
1965	Seed 27	1908 Nov. 13	2418259·682	2·295	− 19·7	7	− 4·7
2014	Seed 27	Dec. 9	8285·638	3·253	+ 86·9	4	− 4·1
4834	Seed 30	1912 Feb. 12	9445·602	2·577	+ 21·1	6	+ 7·7
4850	Seed 30	Feb. 20	9453·612	3·444	+ 96·7	5	− 5·9
4854	Seed 30	Feb. 23	9456·639	2·900	+ 45·8	5	− 7·4
4856	Seed 30	Feb. 27	9460·629	3·319	+ 97·4	4	+ 1·2
4859	Seed 30	Feb. 28	9461·597	·716	+ 44·5	5	− 4·0
4870	Seed 30	Mar. 5	9467·603	3·151	+ 80·3	7	− 2·0
4881	Seed 30	Mar. 12	9474·563	2·968	+ 68·0	5	+ 6·0
4884	Seed 30	Mar. 13	9475·506	·340	+ 95·9	6	+ 6·3
5171	Seed 27	Aug. 27	9642·866	3·424	+ 109·7	5	+ 7·3
5178	Seed 27	Aug. 29	9644 857	1·844	− 41·8	4	− 4·4
5219	Seed 23	Oct. 4	9680·834	2·109	− 29·1	8	+ 1 9
5237	Seed 23	Oct. 7	9683·846	1·550	− 35·1	7	− 2·4
5248	Seed 27	Oct. 16	9692·926	3·488	+ 108·0	4	+ 4·0
5252	Seed 27	Oct. 17	9693·911	·902	+ 26·6	5	+ 2·6
5266	Seed 27	Oct. 30	9706·739	3·015	+ 70·6	7	+ 3·6
5291	Seed 23	Dec. 20	9757·652	·361	+ 93·1	7	+ 5 4
5300	Seed 27	Dec. 21	9758·669	1·378	− 13·3	2	+ 7·7
5302	Seed 27	1913 Jan. 1	9769 686	1·681	− 41·0	5	− 4·4
5307	Seed 27	Jan. 8	9776·610	1·463	− 21·2	7	+ 7·4
5313	Seed 27	Jan. 12	9780·650	1·932	− 30·0	7	+ 5·6
5320	Seed 27	Jan. 22	9790·672	1·240	− 10·6	6	+ 1·4
5329	Seed 27	Jan. 28	9796·642	·067	+ 98·9	6	− 4·7
5348	Seed 23	Feb. 6	9805·593	1·876	− 41·5	9	− 4·5
5359	Seed 27	Feb. 12	9811·556	·697	+ 42·0	5	− 8·0
5369	Seed 27	Feb. 17	9816·522	2·091	− 31·1	5	− 2·0
5433	Seed 27	Mar. 12	9839·536	·107	+ 108·1	4	+ 5·0

Using the adopted value of the period our observations of the main component were combined into ten groups as follows :

NORMAL PLACES

	Mean Phase	Mean Velocity	Weight	Residual O−C	Equation −− Ephemeris
1	3·420	+ 102·98	1·8	+ 1·35	+ ·07
2	·234	+ 97·95	2·3	+ ·57	+ ·09
3	·771	+ 37·70	1·5	− 3·37	+ ·07
4	1·362	− 15·91	1·5	+ 6·04	− ·12
5	1 604	− 37·56	1·2	− 2·97	− ·03
6	1·889	− 37·53	2·0	− ·97	·00
7	2·170	− 26·31	2·0	− 1·66	− ·12
8	2·577	+ 21·10	0·6	+ 7·51	− ·14
9	2·934	+ 56·90	1·0	− ·92	+ ·08
10	3·121	+ 78·00	1·8	− 1·22	+ ·14

The following elements were adopted as preliminary for the least squares solution

$$P = 3{\cdot}5712 \text{ days}$$
$$e = {\cdot}02$$
$$\omega = 0^\circ \text{ (fixed)}$$
$$K = 71 \text{ km.}$$
$$\gamma = +\ 29{\cdot}58 \text{ km.}$$
$$T = \text{J. D. } 2417168{\cdot}171$$

Where the eccentricity is small, as in this case, the coefficients of ω and T are nearly identical and the solution becomes indeterminate, hence ω is here considered fixed. The solution for the other elements γ, K, e and T gave these corrections :

$$\delta\gamma = +\ {\cdot}14 \text{ km.}$$
$$\delta K = +\ {\cdot}13 \text{ km.}$$
$$\delta e = +\ {\cdot}035$$
$$\delta T = \pm\ {\cdot}000 \text{ days.}$$

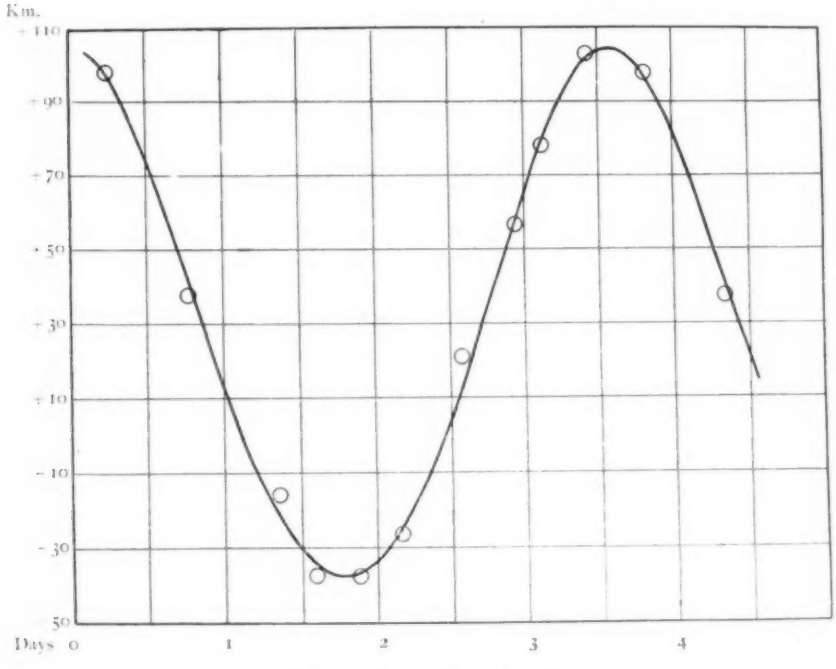
The sum of the squares of the residuals for the normal places was thereby reduced from 182·8 to 130·4 and one solution was sufficient. The corrected values of the elements with their probable errors follow :

$$P = 3{\cdot}5712 \text{ days}$$
$$e = {\cdot}055 \pm {\cdot}019$$
$$\omega = 0^\circ$$
$$K = 71{\cdot}13 \text{ km.} \pm 1{\cdot}11 \text{ km.}$$
$$\gamma = +\ 29{\cdot}72 \text{ km.} \pm 0{\cdot}94 \text{ km.}$$
$$A = 75{\cdot}04 \text{ km.}$$
$$B = 67{\cdot}22 \text{ km.}$$
$$T = \text{J. D. } 2417163{\cdot}171 \pm {\cdot}011.$$
$$a \sin i = 3{,}487{,}600 \text{ km.}$$

The data regarding the second component follow :—

Plate	Velocity referred to γ-line		Lines	Weight	$\frac{m_s}{m}$
	Primary (computed)	Secondary			
4850	+ 72·9	− 113·0	2	1	·65
5219	− 60·7	+ 15 ·9	2	1	·40
5237	− 62·4	+ 164·8	2	1	·38
5313	− 65·3	+ 140·4	2	1	·46
5329	+ 73·9	− 111·8	3	1	·66
5348	− 66·7	+ 163·3	7	3	·41
5369	− 58·8	+ 114·1	1	½	·52

The number of lines and weight refer of course to the secondary component and it is thus seen that the information we have regarding it is meagre indeed. The spectrum appears



VELOCITY CURVE OF *d* TAURI

to be a duplicate of that of the main star. The ratio of the masses is given in the last column and the result of the weighted mean is

$$\frac{m_s}{m} = \cdot 47.$$

This may be taken as provisional; another season it is hoped that more plates of this star on the Seed 23 emulsion will be obtained and then a more accurate determination of the ratio of the masses can be made.

The probable error of a plate is $\pm$ 3·44 km. per sec. The curve represents the corrected elements, the grouped observations being shown.

[Note added while going through the press].

After the above was in the printer's hands the determination of the orbit of this same star by Wilson, of the Lick Observatory, came to hand. Though this binary was discovered at Mt. Hamilton it was on Dr. Campbell's suggestion that its orbit was undertaken here. Apart from the negative maximum the curves are quite similar. The periods are the same. No mention is made of the second component in Wilson's paper.

DOMINION OBSERVATORY,
OTTAWA, CANADA.
April, 1913.

MEETINGS OF THE SOCIETY

AT TORONTO.

April 1.— The President in the Chair.

The paper for the evening was by John A. Paterson, K.C., M.A., on "The Life and Work of the Great American Astronomer, Simon Newcomb."

The lecturer gave a delightful review of the career of Newcomb from his birth in 1835 to his death in 1909. Some of the reminiscences of the astronomer were recounted and many of the problems with which his name has been associated were enumerated.

The paper was appreciatively discussed by several of the members.

April 15.— The lecture of the evening was given by Mr. R. M. Stewart, M.A., on "Work at the Dominion Observatory at Ottawa."

Mr. Stewart gave a short account of the commencement of the work and the growth in the past eleven years, the period during which he has been attached to the Observatory Staff. A number of slides were shown to illustrate the development.

The various Departments of the work were enumerated and an outline of the details of the work given.

An account of the progress of the Boundary Surveys, the Geodetic Branch and the Latitude and Longitude Determinations was given and illustrated by slides of the instruments used, and the method of use of these instruments was described. Then the work in Seismology was given in a similar manner; and an inter-

esting description of the use of the seismograph in obtaining microscisms and in measuring tidal effects in the earth.

The work in terrestrial magnetism was discussed briefly. Then the work in Astrophysics was given in detail and slides of the instruments in use were shown. A brief description of the proposed work in stellar photography and photometric work followed. Then was described the work in Astronomy of Position, which is the Department in charge of Mr. Stewart; and slides of the Meridian Circle and accessories were shown. A short account of the work in the time service was given and with the assistance of views of the Control and Subsidiary Clocks, the details of correction and transmission of the time were explained

April 24.— Special meeting, in the Physics Building of the University, the President in the chair.

Lecture for the evening by Professor Frank Schlesinger on "Celestial Photography."

With a view to stimulating and maintaining the general interest in astronomy throughout the country the General Council of the Society, after consulting the Executive of the various Centres, decided some little time ago to endeavor to secure the services of some eminent astronomers from abroad to lecture before the Centres successively — as far as possible — at least once a year.

The first of these annual lectures was given this year by Professor Frank Schlesinger, Director of the Allegheny Observatory, noted particularly for his contributions towards the determinations of stellar parallax.

Professor Schlesinger selected "Stellar Photography" as the subject for these lectures. The first lecture was given at Ottawa on April 22nd, the second at Peterborough on April 23rd, the third at Toronto on April 24th, the fourth at Guelph on April 25 and the fifth and concluding one at Hamilton on April 26th.

By the aid of beautiful and recently taken lantern slides the marvellous advances that have recently been made in the

field of astronomical research, particularly by the aid of the photographic plate were clearly and eloquently shown.

From each Centre come reports of large audiences and words of appreciation of the lecture. The Centres at Winnipeg and Regina were omitted from the course only on account of the great distance from headquarters, but it is hoped that some way may be found in the near future to enable all Centres to participate in these annual lectures and thus emphasize and maintain the national character of the Society.

April 29.— The President in the chair.

Professor Chant gave the predictions for the next two weeks.

A number of articles of general interest to the members appearing in publications of other societies were referred to.

The paper for the evening was by Professor Chant and dealt with the numerous reports he had received describing the meteoric display on the night of February 9th. The remarkable thing about the display appeared to be that many of the meteors maintained their apparent identity within the earth's atmosphere for a distance of more than 2500 miles. It was announced that the paper in full will appear in the forthcoming number of the Society's JOURNAL.

The reading of the paper was followed by considerable discussion.

May 13.— The Secretary of the Society read a communication from the Royal Society of Canada, inviting delegates from the R.A.S.C. to their annual meeting. It was suggested that the Council name Mr. R. M. Stewart and Dr. R. E. DeLury as delegates.

Mr. G. A. Annett, Cairo, Ont., was elected a member of the Society.

The lecture of the evening was given by Mr. Peter Trout, on "Experiences in Alaska." Mr. Trout gave an interesting series of reminiscences of his early life and the men of prominence he had met, such as John Muir, the botanist, and of his various expeditions as a prospector and miner in Alaska, Mexico and Cobalt.

L. G.

AT HAMILTON

April 26.— Although Saturday is a somewhat inconvenient evening the members of the Centre turned out in goodly numbers to enjoy the treat of listening to a lecture by Dr. F. Schlesinger on "Celestial Photography."

The lecturer stated that the late Thomas Dick had called attention to the possibilities of photography. He then described the early attempts made by various men and the success attending these efforts. Slides showing the results of this early work were given and then the modern and more precise work was illustrated and described.

The fact that by this lecture each hearer was being brought into direct communication with the work of one of the great observatories and with one of the masters in his chosen sphere was much appreciated, and a hearty vote of thanks was accorded the lecturer at the close of what had been to all a most enjoyable evening. Many expressed the desire of being able to avail themselves of Dr. Schlesinger's invitation to visit Allegheny Observatory at any time "day or night."

May 30.—A. A. Hibner, M.A., Ph.D., lectured this evening on "The Astronomical Yard-Stick."

As there are three feet in a yard so there were three sections to the lecture. 1st, as it referred to the earth. 2nd, concerning the forces existing between the sun and the earth, and 3rd, the stars.

Under the first head the lecturer referred to the shape and size of this earth and the various ages it had passed through. Solar discoveries of tropical flora and fauna proved the existence there of much milder climates in time past. The explanations of this were numerous but none were conclusive.

Under the second head reference was made to the force of gravitation and the sun's prodigality in the matter of heat and light. The sun's distance was taken as the first yard stick for measuring the distances of the planets but was afterwards

replaced by the light year for measuring the distances of the stars.

Under the third heading the star distances and sizes were discussed.

This was the last lecture of the season, so the president announced that fortnightly meetings for observation would be held at his observatory till the fall term started.

T. H. W.

At Peterborough

April 23.— An audience of about 400 greeted Professor Frank Schlesinger, of the Allegheny Observatory, who addressed the meeting on "Celestial Photography." The development of this branch of science was outlined and its application to the various problems of astronomy fully explained. By means of photography the work of the astronomical draughtsman and computer was much shortened and made more accurate.

The application of photography to the study of sun-spots, of the chromosphere and corona, of the moon's face, of Mars and the other planets, of the configuration of the stars and their distances was fully explained and illustrated with slides.

Three new members were elected: Messrs. N. C. Mills, B.A.Sc.; A. Fowler, Phm.B., and Rev. T. J. Mansell.

Professor Schlesinger reached Peterborough on the afternoon train, and was welcomed by the members of the Society, who later tendered him a dinner at the Oriental Hotel.

During his stay in the city he was the guest of Mr. and Mrs. H. O. Fiske.

D. B. M.

At Winnipeg

April 2.— At this meeting Mr. H. W. Malpass presented the following report on the "Lunar Eclipse, March 22nd, 1913." The observations were made with the assistance of an 8½-inch reflector.

At 2h 30m a.m., clouds began to gather, and it seemed as though we were doomed to disappointment.

The moon shone out through the rifts in the clouds, however, and we determined that if nothing better offered itself, we would, at least, have an occasional glance. By $3^h\ 10^m$ a.m., the clouds had wholly dispersed, and the full moon shone as brightly as before. From this on, we kept the equatorial directed on the moon, using power "45" for the purpose of gaining as large a field as possible.

At $3^h\ 16^m$ a.m. the moon's edge touched the penumbra, but it was not until $3^h\ 45^m$ that any perceptible diminution of light became apparent. At this time the floors of Grimaldi, Mare Humorum, assumed a hazy appearance, and even the bright streaks of Tycho lost some of their lustre. From this on, the light of the moon gradually became duller, and the penumbra was distinctly perceptible even to the naked eye.

As early as $4^h\ 11^m$ a.m., the S. E. limb began to assume a straightened appearance, and through the telescope the shadow could be seen approaching.

We caught the first contact at exactly $4^h\ 13^m$. The shadow came on directly over Rocca and Crüger, and at $4^h\ 15^m$ Grimaldi began to be obscured.

It was interesting to watch this large crater gradually disappear in the black shadow: it became fainter and fainter, and at $4^h\ 17^m$ disappeared entirely.

The shadow now crossed the Mare Humorum, blotting out its craterlets, and began to extend towards the streaks of Tycho.

At $4^h\ 29^m$ Kepler was reached by the shadow, and at $4^h\ 32^m$ Copernicus was lost to view. At $4^h\ 37^m$ the edge of the greyish shadow became apparent over the two craters in Plato, and at $4^h\ 40^m$ Plato had disappeared. One-half of the lunar disc was eclipsed at $4^h\ 44^m$ and by $4^h\ 51^m$ Ptolemy and Hipparchus were in the shadow. It was interesting to note that the edge of the shadow assumed a jagged appearance, which seemed to jut out in places.

By $4^h\ 59^m$ only a crescent of dazzling light could be seen. The sight was indeed a truly magnificent one. The constellations shone out brilliantly; the air was calm and perfectly still.

At $5^h\ 5^m$ only an irregular wisp of light, which seemed to throw out wings towards the blackened sky, could be seen. This had narrowed down to a very thin streak by $5^h\ 10^m$, and although the total phase began one minute later, a wisp of light lingered obstinately, and did not disappear until $5^h\ 20^m$ a.m.

For the most part the lunar surface was entirely invisible, except for a copper-colored area on the S. W. region. This seemed to grow fainter, and $5^h\ 30^m$ a.m. was scarcely perceptible at all. At this stage, we gave up our observations, but on looking out at $5^h\ 35^m$ I failed to see the moon at all. It seems to me that we had what is known as a black eclipse, a circumstance which does not often occur, and the cause of which is not entirely known. The moon set during the total phase, but I did not carry observation any further than $5^h\ 35^m$ a.m., as the eclipsed moon had gone behind the surrounding buildings, and beyond the reach of the telescope.

C. E. B.

At Regina

February 7.—The Society met in the Collegiate Institute. In the absence of the President, the Vice-President, Mr. Jas. Duff, M.A., occupied the chair.

Mr. George Simpson gave a very interesting and carefully prepared paper on "Ancient Astronomy." All present enjoyed this presentation of this subject and, for the most part, were surprised at the peculiar stages of existences through which the regard for astronomy has passed.

By referring to Carlyle's "Heroes and Hero Worship," the speaker pointed out that the earliest astronomy was rather in the form of worship, as the Gods of the Norsemen were the sun, moon and stars. In Celtic astronomy, at a later date, we find more of the science of astrology although their knowledge of astronomy was probably further advanced. Babylonian astronomy was still further developed and evidences and records are made of the uses of instruments in observations of the heavenly bodies.

The speaker then referred to the work of the Greek astronomers, dealing in turn with Pythagoras, Aristarchus and Hipparchus.

Pythagoras believed the earth to be round but immovable and at the centre of the universe. The greatest gain from his investigations was probably his bold theory that the earth was a sphere resting on nothing. Ideas that are common enough to-day, because we are familiar with them from early youth, were tremendous in conception at that time. Aristarchus was the first astronomer to develop along scientific lines the fact that the apparent motions of the heavenly bodies could be explained by supposing the earth to rotate and revolve. Of all the ancient Greek astronomers we usually consider Hipparchus the most outstanding. His systematic records and careful observations were much to be admired. It was left to Ptolemy, some years after Hipparchus, to work out these theories and give to the world the conception of astronomy which it held for some 1400 years. When we consider that from Pythagoras to Ptolemy was 700 years and from Ptolemy to Copernicus was 1400 years and from Copernicus to modern times some 400 years we may form some ideals as to the influence of the Ptolemaic theory.

Mr. Simpson then explained this theory and finally gave a short account of the investigations of Copernicus and Kepler, which must be regarded as the beginning of modern astronomy.

March 14.— Mr. Trant began his lecture on "Shadows" by calling attention to the scientific definition of a shadow as being caused when streams of radiant energy (which when falling upon the retina excite the sensation of vision) are intercepted by an object partially or wholly unable to transmit them. He said this portion of the subject was too obstruse for a general audience on account of the knowledge of advanced mathematics required, especially as wave-motion was concerned, which was, perhaps, one of the most intricate subjects in existence. He called attention to it simply on account of its historical interest. When the Undulatory Theory was first launched objection was

made that it failed to explain shadows. Thanks, however, to Fresnel it was ultimately shown that it was precisely in that department of science that the theory secured its greatest triumph. This was very important and very interesting.

The lecturer then gave the physicist's definition of a shadow as follows :— That when a light falls upon an opaque body it could not penetrate into the space immediately behind, the space is called a shadow.

As light was invisible and only revealed itself when it fell upon an object so shadow, that was the absence of light, was also invisible and only revealed itself when it fell on an object though it filled the intervening space though invisible. A simple experiment showed this. Take a stick casting a shadow on the floor or on a table, The space between the visible shadow and the stick was full of shadow as would be shown by placing the hand or piece of paper or any object within the area. When the source of light was a point, the shape and dimensions of the shadow were described by a line moving tangentially and this he explained by a diagram on the blackboard. He said light moved in straight lines and when its source was a luminous body, as distinguished from a luminous point, there was more than the shadow or umbra ; there was a fringe of fainter shadow, called a penumbra. This was because light proceeded in parallel rays and caused a shadow, a fainter one, of what might be called the outlying portions of the opaque body. Hence it was that shadows generally were not sharply defined, but shadows caused by the electric arc light (practically a point) had no penumbra and were, therefore, sharply defined.

Mr. Trant then explained eclipses, which were caused by the shadow of the earth in lunar eclipses and by the moon in solar eclipses, and showed how the length of the shadows were calculated. By a diagram on the blackboard he showed that a shadow of a sphere took the form of a cone and the length of the earth's shadow varied between 51 and 57 times the terrestrial radius. The distance between the sun and moon varied between 55 and 63 such radii. If, therefore, the point

of the shadow cone reached beyond the surface of the earth the eclipse would be total for places within the small cone. If it fell short of the earth's surface, only partial; while those observing along the axis of the cone would see an annular eclipse. The moon's shadows move very rapidly across the earth. The moon's orbital velocity was 2120 miles an hour, the shadow moves at the same rate but since the earth rotates in the same direction at 1040 miles an hour the motion of the shadow is 2120 – 1040 or 1080 miles an hour.

It was seen from the diagram that the two cones formed similar triangles and, therefore, we had this ratio

$$\frac{\text{Distance of Sun}}{\text{Length of Shadow}} = \frac{\text{Diameter of Sun}}{\text{Diameter of the Sphere}}$$

and this showed that the shadow of a body in sunlight was about 110 times as long as the body was broad.

Mr. Trant then went on to say that anyone who noticed the lengthening and shortening of shadows according to the altitude or declination of the sun could not but be struck with the existence of a relationship between them. The relationship was fully explained by the trigonometrical solution of a triangle and on the blackboard the lecturer worked out the height of buildings from the length of the shadows cast according to the altitude of the sun. An interesting part of the lecture at this point, was that Mr. A. J. Pyke with a sextant obtained the altitude of the light at the ceiling of the room, and measuring the length of the shadow on the floor of an object the height of the object was calculated. The lecturer showed that on the 6th March and the 6th September at noon in the latitude of London the sun was at an altitude of 45 degrees and the length of the shadow, therefore, equalled the height of the object. The lecturer then went on to show that by the means indicated the heights of mountains and other inaccessible objects could be ascertained and he then proceeded to describe the micrometer and showed how, by its aid, the lengths of the shadows of the mountains of the moon were ascertained and the heights of the mountains of the moon calculated. The measurement of the length of these shadows was

easy because the moon having no atmosphere there was no diffusion of light and the shadows were bold and distinct.

The latter portion of the lecture was devoted to indicating the necessity of knowledge of shadows in architecture, sculpture and painting. It was important that the architect should know what shadows would be caused by the capitals of columns, filets, cyma-reata, pediments, mouldings, etc., as otherwise the shadows caused might be black places on the buildings instead of producing a softening effect. Speaking of sculpture Mr. Trant pointed out that a celebrated French sculptor had complained that the folds of the skin of Landseer's lions in Trafalgar Square were too deeply furrowed so that no shadow was produced, whereas, if this had been avoided the shadows would have been utilised to have made the folds of the skin look natural and he indicated many errors in this direction that had been noticed in statues and other sculpture work. He then spoke of shadows in pictures and pointed out that the old masters generally introduced light and cloudy shadows that had no existence in nature and sometimes omitted them altogether. He read a portion of Ruskin's "Modern Painters" to show the great change that had come over landscape painting by Turner and his contemporaries who painted shadows just as they were in nature. To illustrate this point he said that an artist taking a bush into his studio would undoubtedly get a correct outline and true color but his picture would be stiff and bald, whereas, if he went into the woods and painted from the bush where it grew there would be countless shadows caused by the leaves themselves upon each other which would make all the difference between a stiff outline and a beautiful picture.

In conclusion Mr. Trant explained the sun-dial and exhibited one that had been specially constructed by a collegiate student for the lecture and suggested that a sun-dial be constructed in grounds of the Collegiate as a perpetual object lesson for the students.

March 31.— Mr. F. A. MacDiarmid, M.A., of the Dominion Observatory, Ottawa, was the speaker of the evening and a goodly number of the members of the Society were present. The President of the Centre, Mr. Hector Lang, B.A., acted as chairman.

Mr. McDairmid took for his subject "The Dominion Observatory," and in his address he outlined the development, the equipment and the functions of the various departments of the Observatory and also explained the very close connection between the results of their work and the every day life of our citizens.

Modern facilities depend to no small extent on the accuracy of astronomical observations, when we think of the value of time to our great commercial enterprise; of the accurate registration of international boundaries and the location of cities and towns; of the records of the great movements of the earth and of the distribution of general information concerning earthquakes, winds, tides, etc.

The lecturer then explained the work of the various departments such as the astrophysical, the seismological, time service, geodetic survey, meridian boundary surveys and geographical determinations. His audience was particularly delighted with his accounts of the instruments and modes of operation in the astrophysical department and of the work of Dr. Otto Klotz in the seismological department. Mr. MacDairmid made special mention of the valuable work done by Mr. R. M. Stewart in the development and management of his department of time service, which he considered one of the finest of its kind on the continent.

Not the least interesting to the members of the Society was the account of the accuracy with which the old time astronomers worked in the early surveys of our Canadian west. Recent surveys show that their work, even though conducted under great difficulties, was most painstaking and careful. The lecturer mentioned many instances of this particularly fine surveying in

early times, one being the international boundary between Yukon and Alaska.

All present enjoyed the address very much and at the close a vote of thanks was tendered to Mr. MacDiarmid for his very able and interesting address. We shall look forward to the pleasure of hearing Mr. MacDiarmid again in the near future.

A. J. P.

NOTES FROM THE METEOROLOGICAL SERVICE

Summary Report of the Weather in Canada

April, 1913

Temperature.— April was on the whole a very mild month over the greater part of the Dominion. The mean temperature was everywhere above the normal, except over a large portion of British Columbia, where it was about normal or slightly below. In the Prairie Provinces, the positive departures were most marked, the excess ranging between three and ten degrees, while from Lake Superior eastward it was between one and four degrees.

Precipitation.— The total precipitation for the month of April was considerably less than the average in British Columbia, Alberta, Saskatchewan, Manitoba, the Rainy River and Thunder Bay Districts of Ontario, and in the Province of Quebec from Quebec City to the Gulf. In New Brunswick and Cape Breton Island there was also a considerable deficiency, but over the greater part of Nova Scotia a large excess. With a few local exceptions, the average precipitation was well exceeded in Ontario.

May, 1913

Temperature.— The mean temperature for May was from one to three degrees below normal over practically the whole of the Dominion. However, over a small area in Southern Sas-

katchewan and in the vicinity of Toronto the normal was slightly exceeded.

Precipitation.— The rainfall during the month was below normal throughout the greater part of the Dominion, the deficiency reaching as high as seventy-five per cent. in Eastern Manitoba, and about seventy per cent. locally in the Peninsula of Ontario. There was an excess, however, in a few localities in British Columbia, in the Ottawa and Upper St. Lawrence Valleys, and in Western Nova Scotia, the positive departure in the extreme west of the latter Province amounting to nearly fifty per cent.

Temperatures for April and May, 1913

Station	April		May	
	Highest	Lowest	Highest	Lowest
Yukon				
Dawson			70	18
British Columbia				
Atlin	42	12		
Agassiz	75	33	78	33
Barkerville	57	8	62	15
Kamloops	78	23	82	30
New Westminster	70	29	77	38
Prince Rupert	57	34	62	36
Vancouver	67	31	72	37
Victoria	67	31	75	37
Western Provinces				
Battleford	83	20	80	25
Broadview	80	20	91	25
Calgary	80	19	80	18
Carman				
Edmonton	79	22	78	23
Medicine Hat	85	20	88	23
Minnedosa	79	16	88	26
Moose Jaw	84	15	91	19
Oakbank	75	19	85	22
Portage la Prairie	82	19	90	20
Prince Albert	76	18	80	20
Qu'Appelle	77	14	87	21
Regina	80	9	90	17
Swift Current	82	18		
Winnipeg	78	19	88	22
Ontario				
Agincourt	78	24	85	27
Aurora	80	24	83	25
Bancroft	83	19	85	20
Barrie			83	27
Beatrice	81	20	80	24
Birnam	78	20	81	23
Bloomfield	85	24	80	29
Brantford	83	24	85	28
Bruce Mines	66	18	80	26
Chatham	82	23	84	28
Clinton	78	21	81	23
Cottam	84	22	84	22
Gravenhurst	82	22		
Guelph	73	25		
Haliburton	85	4	86	18
Hamilton	83	28	88	31
Huntsville	83	20	83	24
Kenora	68	18	84	23
Kinmount	82	20	83	21
Kingston	75	23	74	26
Lakefield				
London	83	21	85	27
Lucknow	78	20	80	19
Madoc	82	22	86	27
Midland				
North Gower	85		87	20
Otonabee				
Ottawa	85	22	86	30
Owen Sound				
Paris	84	26	86	29
Parry Sound	78	19	83	24
Peterboro'	81	22	85	27
Port Arthur	58	20	80	24
Port Burwell	72	24	77	28
Port Dover	77	24	82	27
Port Stanley	71	23	74	25
Ronville	78	18	82	23
Sarnia				
Southampton	77	24	82	25
Stonecliffe	80	20	87	23
Stony Creek	81	30	85	30
Stratford				
Toronto	77	28	87	30
Uxbridge	80	23	83	24
Wallaceburg	79	23	83	29
Welland	80	25	83	31
White River	71	8		
Quebec				
Brome	82	12	83	22
Father Point	62	19	68	24
Montreal	83	22	84	32
Quebec	80	13	84	28
Sherbrooke	85	14		
Maritime Provinces				
Charlottetown	74	21	66	30
Chatham	85	14	88	28
Dalhousie	80	16	73	29
Fredericton	83	15	83	27
Halifax	82	22	66	29
Moncton	79	13	70	26
St. John	61	19	66	31
St. Stephen	82	17	78	22
Sussex	80	12	70	22
Sydney	74	24	70	27
Yarmouth	68	26	60	30

Earthquake Records by the Milne Seismograph

TORONTO

R. F. Stupart, Director.

P.T. = Preliminary Tremors. L.W. = Large Waves. Time is Greenwich Civil Mean Time, 0 or 24 h = midnight.

No.	Date 1913	P. T. Comm.	L.W. Comm.	Max.	End	Max. Amp.	Durat.	Remarks
		h m	h m	h m	h m	mm.	h m	
1241	Apr. 3	16 28·0			16 30·5	0·1	0 2·5	
1242	" 3	17 1·0			17 6·5	0·1	0 5·5	
	" 7	Light turned down at 17·40 to attend to inst. Possibly a small disturbance missed						
1243	" 13	7 27·8	7 39·7	7 45·5	8 33·5	0·2	1 5·7	No defined Max.
1244	" 18	20 18·7			20 51·0	0·050	32·3	Possibly A C at times.
1245	" 24	11 0·0	11 30·2		13 43·0	0·052	43·0	Prolonged small thicken'gs.
1246	" 25	18 18·0	18 26·2	19 19·5	21 38·2	0·3	3 20·2	Prolonged small disturb.
1247	" 26	12 44·0			13 42·0	0·050	58·0	Doubtful as to beginning.
1248	" 29	23 47·2	0 6·8	1 14·6	1 17·7	0·3	1 30·5	Max. not well defined.
1249	" 30	11 47·2 11 50·1	11 52·4	12 13·4	13 9·7	1·4	1 22·5	
1250	May 3	21 23·6			21 25·9	0·050	0 2·3	Doubtful as to being seismic
1251	" 8	18 54·1	19 9·8	19 9·5 19 42·1	21 2·6	0·2	2 8·5	Looks like two distinct quakes.
1252	" 16	12 0·6	12 10·7	12 16·6	12 57·6	0·5	0 57·0	
1253	" 18		2 38·1 3 8·1	3 17·5	4 0·3 4 14·5	0·1		P Ts not recorded.
1254	" 18	13 29·5			13 33·2	0·1	0 3·7	
1255	" 30	12 9·7	12 28·2 12 43·9 12 55·7	12 57·0 13 13·9	14 16·7	0·8 1·3	2 7·0	No defined max.

Period 17·7 seconds. 1 mm. = 0″·59.

VICTORIA, B. C.

E. B. REED, SUPERINTENDENT.

No.	Date 1913	P.T. Comm.	L.W. Comm.	Max.	End	Max. Amp.	Durat.	Remarks
		h m	h m	h m	h m	mm.	h m	
1249	Apr. 3	16 25·5			16 28·7	0·05	0 3·2	
1250	" 3	17 9·8			17 10·8	0·05	0 1·0	
1251	" 7	17 46·2	17 57·1		18 22·4?	0·3	0 36·2	Increasing and decreasing thicken'gs
1252	" 13	7 28·3	7 37·0) 7 40·3)		7 58·9	0·2	0 30·6	Thickening.
1253	" 24	10 36·5 10 38·7		10 42·6 11 32·7	13 57·0	0·2 0·3	3 20·5	Extend'd thickenings
1254	" 25	18 10·0	18 19·7	18 24·6 19 15·4	21 17·0	0·8 1·9	3 7·0	
1255	" 26		12 54·4 12 58·9			0·1		Seismic movements marked by high wind.
1256	May 8	18 47·4	18 57·8	18 59·3	20 3·7	0·3	1 16·3	
1257	" 18	2 21·1	2 31·3 2 48·2	3 14·3	3 53·6	0·3	1 32·5	L. W. continued for a long time.
1258	" 18	13 13·0		13 13·5	13 16·6	0·2	0 3·6	
1259	" 21	14 43·8			15 8·1	0·1	0 24·3	
1260	" 30	12 6·8	12 26·5 12 32·9 12 38·8	12 49·6	15 4·0	7·4	2 58·0	Well spread out movements.

Period 18 seconds. 1 mm. = 0″·54

J. V.

MAGNETIC OBSERVATIONS

The photographic records of the magnetic elements indicate that the magnetic forces have continued very regular during the months of April and May, 1913. On 17 days in April and on 19 days in May the curves of both Declination and Horizontal Force were normal.

In April the only disturbance of any magnitude occurred on the 9th and began gradually at about 4 a.m. Maximum westerly declination 6° 35′·8, was reached at $14^h\ 20^m$ and minimum W. declination 6° 1′·6, at $17^h\ 19^m$, whilst minimum Horizontal Force 0·16076 dynes occurred at $10^h\ 53^m$ and maximum H. 0·16167 dynes at $15^h\ 13^m$.

In May a series of disturbances were recorded commencing on the 4th and continuing until the morning of the 8th when they gradually died away. The maximum of disturbance took place on the 5th and 6th. The Horizontal Force curve was lightly disturbed from early morning of the 4th whilst the Declination curve was normal until $20^h\ 50^m$ when a rapid decrease in W. declination of 38′ in 35 minutes of time was recorded followed by an increase of 40′ in the next hour. The maximum and minimum values for the month of both W. Declination and Horizontal Force were recorded during this series of disturbances.

Declination

Month	Mean of Month	Max.	Date	Min.	Date	Monthly Range	Amplitudes—Mean Daily	
							From hourly readings	From Means of Extremes
1913	° ′	° ′		° ′		° ′	′	′
Apr.	6 17·8	6 35·8	9	5 57·2	12	0 38·6	9·5	13·7
May	6 18·0	6 34·4	6	5 39·4	4	0 55·0	11·8	16·8

Horizontal Force—C.G.S. Units

1913								
Apr.	0·16130	0·16200	8	0·16076	9	0·00124	0·00031	0·00049
May	0·16138	0·16185	5	0·16064	4	0·00121	0·00036	0·00055

Inclination

Month	Mean Earth Inductor
1913	° ′
April	74 40·6
May	74 40·3

ASTRONOMICAL NOTES

Gain of Definition by Moving a Telescope. — A correspondence, *Nature*, April 10th — May 1st, initiated by Mr. M. E. J. Gheury has appeared on the subject of the additional visibility of objects in the field of a telescope when made to move relatively to the field. Mr. Gheury is in the habit of observing the daily drop of the Greenwich time ball from his observatory, three miles distant, and found on an occasion when the air was misty, that, though he was unable to see the ball with his telescope directed on it and at rest, he was able to observe the signal by giving the instrument a small motion so as to make the ball move in the field. Suggestions have been made that the reason may be due to contrast or to averted vision. A letter which may be useful to observers was contributed to the series by Prof. E. E. Barnard, of Yerkes, who said that when sweeping for comets it has happened to him that nebulæ would come into the field which were too faint to be seen with the telescope at rest, but by swinging the telescope to and fro they became readily visible, as though the process of motion had the effect of greatly multiplying the light. He also mentions that he used to find it easier to detect faint nebulæ or comets when they entered the field from a particular side, and naturally took care to sweep so that the stars entered from the favourable direction.—*Journal B. A. A.*, No. 7.

The Energy of the Rotating Earth.— In an introductory lecture to the engineering classes at University College, London, Professor J. A. Fleming, in considering the sources of

energy available to mankind, pointed out that the earth is a great flywheel. It whirls along in its orbit with a velocity of about twenty miles a second or 1,200 times that of an express train. Its rotational energy is a hundred thousand million billion horse-power hours ; but the total orbital energy or energy of motion in its orbit is ten thousand times greater. "Suppose" said Professor Fleming, "we could in some way or other slow down its rotation so as to make the day just five minutes longer. This would decrease the earth's angular velocity by about one third of one per cent and decrease the angular energy by about two thirds of one per cent, or say by 1/150 part. If then we could capture and store up the difference in the rotational energy in the two cases, it would give us about six million billion horse-power hours, or a billion horse-power for seventy thousand years. The energy we can obtain by the combustion of all the one thousand million tons of coal, at present raised per year, sinks into insignificance compared with the enormous energy which would be set free by an almost imperceptible lengthening of the earth's diurnal rotation.

Professor Fleming was not rash enough to indicate in what manner this unthinkable amount of energy could be utilized. Those who will attempt that will find themselves engaged in the mad task of designing perpetual motion machines. — *Scientific American*, April 5.

Radial Motion in Sun-Spots. — The type of vortex indicated is that of the terrestrial tornado or hurricane. There is a whirling upward rush of material from the interior of the sun, which spreads out radially with rapidly decreasing velocity, tangenial to the solar surface, and entrains with it the gases of the reversing layer. The actual vortex is deep-seated, the outflow into the reversing layer being a portion of the upper part of it, the inflow from the chromosphere being a secondary effect, a superficial indication of the underlying vortex in which the magnetic field originates. — C. E. St. John, *Astrophysical Journal*, No. 5.

NOTES AND QUERIES

Communications are Invited, Especially from Amateurs. The Editor will try to Secure Answers to Queries.

Query

Is there any observational evidence that changes have taken place in any nebula?—Winnipeg Centre.

Answer

Professor Heber D. Curtis, of the Lick Observatory, who has made extended studies of the nebulæ, has kindly supplied the following answer:—

"A number of nebulæ have been announced as variable in brightness. For most of these cases the evidence must be regarded as insufficient, and due to the unavoidable personal element entering into the measurement of such difficult objects visually with telescopes of different power. But in the case of Hind's well known variable nebula near *T* Tauri the evidence of variation seems conclusive. Mr. Hind discovered this object in 1852, and at this time and for some years later it was a conspicuous object in an ordinary telescope; it was easily seen and its position measured by D'Arrest, Struve, and Lassell. About 1860 the nebula disappeared in ordinary telescopes; in 1890 Barnard found it so faint that he believed it would be invisible in any other telescope than the 36-inch refractor. A four-hour exposure by Keeler in 1899 with the Crossley Reflector shows it as excessively faint, so faint that I doubt if it could be seen at all visually. Other evidences of nebular variation in this region are noted by Barnard, particularly in the small wisp of nebulosity which is attached to the variable *T* Tauri. Barnard's papers on

this nebula may be found in the *Monthly Notices*, Vol. LV., p. 442, 1895, and Vol. LIX., p. 372, 1899.

For an established case of actual variation in the form of a nebula we have an example only in the case of the nebulosity surrounding the new star Nova Persei. Perhaps this, moreover, is scarcely to be classed as a true nebula, and so difficult is the explanation of this phenomenon as an actual movement of matter away from the Nova, that Seeliger has put forward the theory that we saw there only the successive lighting up of different portions of an irregular nebular mass, already existing near this region, by the intense wave of light sent out by the outburst of the Nova.

No certain evidences of motion have as yet been found in the spirals, perhaps because the interval of time during which they have been under observation with powerful photographic instruments is still all too short (less than twenty years) to show such motion."

Queries

1. In "Astronomical Curiosities," by J. E. Gore, page 79, I find the following: — "Jupiter has been seen on several occasions apparently without his satellites; some being behind the disc, some eclipsed in his shadow, and some in transit across the disc. This phenomenon was seen by Galileo, March 15, 1611; by Molyneux on November 12, 1681; by Sir William Herschel, May 23, 1802; by Wallis, April 15, 1826; by Greisbach, September 27, 1843; and by several observers on four occasions in the years 1867–1895. The phenomenon again occurred on October 3, 1907, No. 1 being eclipsed and occulted, No. 2 in transit, No. 3 eclipsed and No. 4 occulted. It was not, however, visible in Europe, but could have been seen in Asia and Oceania. The phenomenon will occur again on October 22, 1913.

Our Handbook does not state whether it will be visible here. Will it be so? Also, is it possible to see the shadow of a satellite, in transit, on the surface of the planet with a 3-inch telescope?

2. In another place, the same author, discussing the mass of the Andromeda Nebula, refers to a limit to the probable mass of the sidereal universe. How would this estimate be arrived at? Would it be determined by the effect of gravitation upon the solar system? — T. H. W., Hamilton.

ANSWERS

An application to the Dominion Observatory, Ottawa, elicited answers from the Chief Astronomer, Dr. W. F. King, as follows:—

1. "As to the first of the questions, Jupiter will be seen apparently without his satellites on October 21st, 1913. The phenomenon will not be visible in Eastern Canada as Jupiter sets shortly after satellite No. III. disappears on Jupiter's disc and before No. II. disappears. The occulting of No. I. and eclipsing of No. IV. occur still later. In Western Canada, however, the phenomenon should be visible, the four satellites being invisible at $11^h\ 57^m\ 40^s$, Eastern Standard Time.

I think that under the most favorable conditions of seeing, the shadows of the satellites can be seen on the disc of Jupiter with a three-inch telescope, but that the test is near the limit of the power of a telescope of that size.

2. Estimates of the mass of the sidereal universe are necessarily very rough, depending upon many assumptions, some of which may be open to criticism. It is, of course, necessary to assume boundaries at a finite distance. The following estimate was made by Lord Kelvin, (*Baltimore Lectures*, pub. by C. J. Clay and Sons, London, Appendix D. page 534).

'Supposing a sphere of radius $3{\cdot}09 \times 10^{13}$ kilometres (being the distance at which a star must be to have parallax $0''{\cdot}001$) to have within it, uniformly distributed through it, a quantity of matter equal to one thousand million times the sun's mass; the velocity acquired by a body placed originally at rest at the surface would in five million years, be about 20 kilometres per second, and in twenty-five million years would be 108 kilometres per second (if the acceleration remained sensibly constant for so long a time). Hence, if the thousand million suns had been given at rest twenty-five million years ago, uniformly distributed throughout the supposed sphere, many of them would now have velocities of 20 or 30 kilometres per second, while some would have less and some probably greater velocities than 108 kilo-

metres per second; or, if they had been given thousands of millions years ago at rest so distributed that now they were equally spaced throughout the supposed sphere, their mean velocity would now be about 50 kilometres per second.* This is not unlike the measured velocities of stars, and hence it seems probable that there might be as much matter as one thousand million suns within the distance $3{\cdot}09 \times 10^{16}$ kilometres. The same reasoning shows that ten thousand million suns in the same sphere would produce, in twenty-five million years, velocities far greater than the known star velocities: and hence there is probably much less than ten thousand million times the sun's mass in the sphere considered.' "

KIND WORDS FOR THE JOURNAL

In the *Home University of Modern Knowledge*, a series of small but authoritative works published by Williams & Norgate, London, is a volume on "Astronomy" by Arthur R. Hinks, lately appointed to the chair of astronomy in Gresham College, London; and in it is the following good advice:—

"To keep abreast of recent work the student must refer to the periodicals . . . . . *The Journal of the British Astronomical Association*, *The Publications of the Astronomical Society of the Pacific*, and THE JOURNAL OF THE ROYAL ASTRONOMICAL SOCIETY OF CANADA are all full of interesting matter."

DEATH OF PROFESSOR LEON

Professor Luis G. León, well known as the perpetual general secretary of the Astronomical Society of Mexico, died on April 23, 1913. He took a very active interest in the subject and as the editor of the Society's *Bulletin* he did much to advance astronomy in his country. Professor León was an honorary member of R.A.S.C., and some of his observations of sun-spots have been published in this JOURNAL.

C. A. C.

* *Phil. Mag.*, August, 1901, pp. 169, 170.